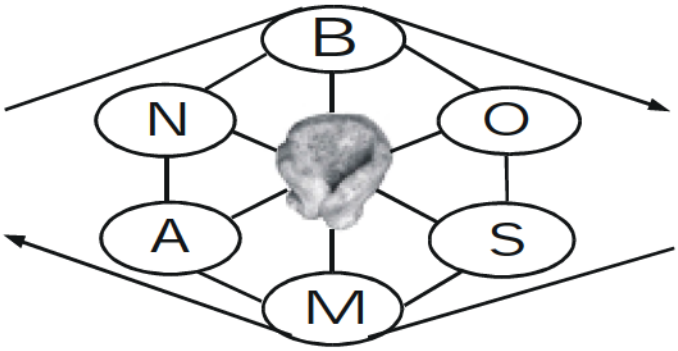
Technical Cruise Report

- POS 254 -

Research cruise with RV Poseidon, cruise no. POS 254:
24 July 1999 (Reykjavik) - 08 August 1999 (Bremerhaven)

Boreale Schwämme
als marine Naturstoffquelle
(BOSMAN)



BOSMAN-Partners

Universität Hamburg
Universität Göttingen
Universität Tübingen
Universität Bonn
Technische Universität Berlin

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Max-Planck-Institut für Verhaltensphysiologie, München

funded by:
BMBF / BEO Rostock-Warnemünde (Project No. 03F0256A - D)

Hamburg, April 2000

C R U I S E R E P O R T

R.V. „POSEIDON“ **Cruise No.:** POS 254

Dates of Cruise: July 24 to August 06, 1999

General subject of research: biological oceanography

Port Calls: Reykjavik (IS) - Bremerhaven (GER)

IfM-Department / CAU Institute:

Chief Scientist: Prof. Dr. W. Michaelis, Institut für Biogeochemie und Meereschemie der Universität Hamburg

Number of Scientists: 12

Project: **Boreale Schwämme als marine Naturstoffquelle (BOSMAN)**

funded by:
BMBF / BEO Rostock-Warnemünde (Project No. 03F0256A - D)

Cruise Report

This Cruise Summary Report consists of 65 pages and covers:

1 List of cruise POS 254 scientific participants

2 Research Programme

3 Cruise Narrative

4 Individual scientific reports and first results

Appendix A: Operation Statistics

Appendix B: MS Profiles

Appendix C: Waterchemical Data of the MS Stations

Contents

1 List of cruise POS 254 scientific participants 1

2 Research Programme *(V. Thiel, T. Pape, W. Michaelis)* 2
2.1 Working Area 2
2.2 Cruise Objectives 3

3 Cruise Narrative *(T. Pape)* 5

4 Individual scientific reports and first results 7
4.1 Work Report of the Coral-Sponge-Habitat Mapping Team 7
(A. Freiwald, V. Hühnerbach, J. Campbell)
4.1.1 Introduction 7
4.1.2 *Lophelia*-occurences in Scandinavian shelf and fjord settings 7
Topographic and oceanographic background 7
POS 254 study site: Sula Ridge 8
Seafloor topography and sedimentary facies on the Sula Ridge 10
4.1.3 Habitat mapping during POS 254 12
Echosounding surveys 12
Sidescan sonar operations 13
Sidescan sonar survey 15
First results 17
4.1.4 Grab sampling 20
4.1.5 Dredge sampling 20
4.1.6 Dives with the manned submersible JAGO 20
Operational notes 21
First results 22
References 27

4.2 Oceanography and Waterchemistry at Sula Ridge *(T. Pape)* 29
4.2.1 Introduction 29
4.2.2 Instrumentation 29
4.2.3 Sampling and analytical methods 29
4.2.4 First investigations and results 33
References 40

4.3 Sponges and Sponge distribution of the deep water *Lophelia pertusa* reefs of the Sula Ridge area (*J. Reitner)* 41
4.3.1 Introduction 41
4.3.2 Rocks 42
4.3.3 Softbottom close to the reefs 42
4.3.4 Softbottom far from the reefs 43
4.3.5 Lophelia - Reef environment 43

4.4 Sponge-associated bacteria in a boreal deep water reef system 45
(Gabriela Schumann-Kindel)
4.4.1 Introduction 45
4.4.2 Cultivation strategy 47
Anaerobic cultivation 48
Aerobic conditions 48
4.4.3 First results 49

Appendix A Operation Statistics

Appendix B MS Profiles

Appendix C Waterchemical Data of the MS Stations

1. List of cruise POS 254 scientific participants

name	institution	task/responsibility
Walter Michaelis	IfBM	chief scientist
Richard Seifert	IfBM	station work and water chemistry co-chief scientist
Thomas Pape	IfBM	water chemistry, sample documentation and preparation
André Freiwald	IMGPT	geology and biology
Joachim Reitner	IMGPG	zoology and taxonomy
Gabriela Schumann-Kindel	ÖdM	microbiology
Ines Kaesler	ÖdM	microbiology
Jürgen Schauer	MPI	submersible pilot
Karen Hissman	MPI	submersible technical and instrumental handling
Veit Hühnerbach	SOC	side scan sonar handling
Jonathan Campbell	SOC	side scan sonar handling
Pål Buhl Mortensen	IMR	oberserver, biology

IfBM Universität Hamburg, Institut für Biogeochemie und Meereschemie, Bundesstrasse 55, D-20146 Hamburg

IMGPT Universität Tübingen, Institut und Museum für Geologie und Paläontologie, Herrenberger Strasse 51, D-72070 Tübingen

IMGPG Universität Göttingen, Institut und Museum für Geologie und Paläontologie, Goldschmitdtstrasse 3, D- 37077 Göttingen

ÖdM Technische Universität Berlin, Institut für Technischen Umweltschutz, Fachgebiet Ökologie der Mikroorganismen, Franklinstrasse 29, D-10587 Berlin

MPI Max-Planck-Institut für Verhaltensphysiologie, AQUATEC, D-82319 Seewiesen

SOC Southampton Oceanography Centre, University of Southampton, Highfield, Southampton SO17 IBJ, UK

IMR Institute of Marine Research, Postboks 1879 Nordnes, N-5817 Bergen

2. Research Programme *(V. Thiel, T. Pape, W. Michaelis)*

Through improved biological screening methods, the importance of natural products in drug discovery has greatly been enhanced during the last years. This is particularly true for marine natural products, which show a huge array of diverse and novel structures with potent biological activities. As a result of their sessile nature many marine organisms evolved a rich inventory of chemical compounds used for their defense, reproduction and communication. Several of these compounds have become promising candidates as new drugs for the treatment of human diseases. In 1998, the German Ministry of Education and Research (BMBF) has launched the priority programme 'Marine Natural Products Research' to promote the search for marine substances with interesting biological and pharmaceutical properties.

The research programme BOSMAN is a multidisciplinary approach, which aims to enlighten the complex array of factors controlling the biosynthesis of natural products in the marine environment. Thus, BOSMAN involves scientists from chemical, biological and geological fields.

Sponges (porifera) are the primary target organisms of BOSMAN. At least 8000 species occur in nearly all contemporary aquatic environments and have developed an exciting variety of strategies for competing even under unfavourable ecological conditions. Due to their sessile, exposed habit, sponges are one of the richest phyla in toxicogenetic species. Within the frame of this study, the mission of BOSMAN is to access and study the diversity of chemicals present in the particular environments of Northeastern Atlantic deep cold-water reefs.

2.1 Working area

A sampling campaign was performed at Sula Ridge, ca. 50km off the Norwegian coast (near Kristiansund) in 1999 (POS 254, 24.07.99 - 06.08.99). The Sula Ridge reef complex belongs to the Northeastern Atlantic deep cold-water reefs,

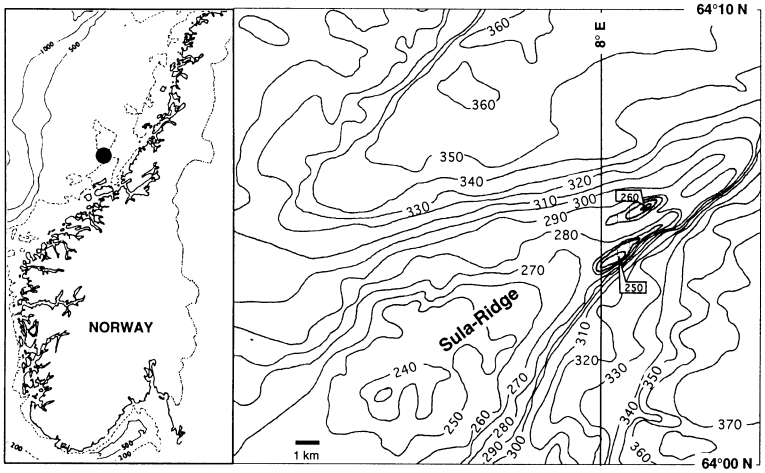


Fig. 2.1.-1. Working area at Sula Ridge, mid-Norwegian shelf

built by azooxanthellate scleractinian corals (most prominent: *Lophelia pertusa*), that show a belt-like distribution from offshore Northern Norway to the Canary Islands in water depths between 200 and 1200 m. Former investigations at Sula Ridge indicated a high biodiversity associated with the reef structure.

2.2 Cruise Objectives

The main cruise objectives of POS 254 were

- to conduct side-scan sonar (SSS) surveys over specific parts of the coral mound complex and adjacent areas, which have not been studied during previous research cruises on the Sula ridge. Sonographs obtained during former cruises (e.g. Victor Hensen 24/95) delivered detailed information on the coral reef geometry with respect to different hard substrates, such as outcropping lithified sandstones and morainic deposits. Additionally, echosounder records were taken in order to create a high resolution seafloor topography map of the studied sector.

- to examine oceanographic and marine chemical conditions within the reef ecosystem. A CTD-probe was used to measure temperature, salinity, pressure and conductivity along selected profiles. Specific water samples were taken by a rosette water sampler for measurements of particulate organic material, dissolved organic carbon, dissolved inorganic carbon, dissolved oxygen, nutrients, volatile hydrocarbons (C_1 - C_4), and pH.

- to collect a great variety of sponges associated with the coral reef structures at Sula Ridge considering minimized damage to the reef and the sampled specimen neither mechanically nor ecologically. A very selective sampling of the materials desired was enabled by the highly manoeuvrable manned submersible ‚JAGO' equipped with a precise working manipulator.

- to document faunal occurence and abundance of sponges in dependence of environmental conditions within the coral reef area. Previous investigations (e.g. POS 228) indicated the presence of a highly diverse and zonated sponge fauna at Sula Ridge. During POS 254 a total of 12 hours were recorded on digital video tapes and nearly 400 photographs were taken. These detailed recordings show distinct distribution zones of specific sponges.

- to take samples of selected species for cultivation studies of boreal sponge associated bacteria immediately after recovery on board. In general, sponge associated microorganisms are assumed to be potential producers of marine natural products. Furthermore parts of interesting sponge specimen have been fixated for molecular analysis and taxonomical studies ashore.

- to preserve sponge samples until further biochemical investigations at our laboratories. Besides inventory analysis of primary products special emphasis is laid on studies of secondary chemical compounds which may possess a variety of pharmaceutical activities.

3. Cruise Narrative *(T. Pape)*

The charter period of cruise POS 254 started on July 24th, 1999, in Reykjavik (Iceland). Scientists of the BOSMAN project (Univ. Hamburg, Univ. Tübingen, Univ. Göttingen, TU Berlin) as well as scientific (University of Southampton, Institute of Marine Research, Bergen) and technical (Max-Planck-Institut, München) supporting participants joined the cruise on board the R/V POSEIDON.

The loading of the container and the airfreight with scientific equipment was carried out in the morning of July, 23th. The afternoon was used to unpack the equipment, prepare the laboratories and install the analytical instruments. Due to use during POS 253 the submersible JAGO was already on board.

R/V POSEIDON left Reykjavik on July 24th at 9.00 p.m. steaming directly towards the investigation area with an average speed of 9,5 to 9,8 knots. As the transfer to Sula Ridge lasted about 4 days and 15 hours, the station work was started in the early morning of July, 28th. Because of gusty wind there was a rather high swell in the investigation area.

For economical reasons it was planned to realize station works during POS 254 in a diurnal order:

1) Two dives at selected reef sectors with the manned submersible JAGO at day time.
2) Hydrocasts at day time inbetween JAGO-dives.
3) Echosounding and side scan sonar mapping preferentially during night time.
4) Occasional bottom sampling in distinct off-reef sites using a Van Veen grab and a dredge.

At first, a hydrocast (01 MS, *ship station 387*) was carried out at 64:04:25N, 08:01:50E. (Since problems concerning the rosette water sampler occured at 01 MS, a further hydrocast station (27 MS) was done during the cruise close to this location). Subsequently echosounding and side scan sonar surveys were carried out alternately. At day time weather conditions prevented the handling of JAGO and therefore mapping procedures were continued until the late afternoon. To obtain biological samples it was then decided to utilize a dredge (04-1DR and -2DR) and on July 29th a Van Veen grab (07BG to 15BG) at off reef sites.

In the morning of July 30th, improved weather conditions allowed a first submersible dive (18 JA). The sea stayed calm further on and thus we could realize

two dives per day until leaving the study area. In total 8 dives and 8 hydrocasts were performed during POS 254 and approximately 11 km^2 of Sula Ridge area were covered by side scan sonar survey. For detailed information and complete statistics, see chapter 4 and Appendix A.

In the morning of August 3rd, station work was completed by a hydrocast station (34 MS, *ship station 443*) at 64:03:20N, 07:57:40E and the study area was left to steam towards Bremerhaven. Having arrived at the port in the morning of August 6th, the equipment and the samples were unloaded and stored for direct transport to our laboratories by vans. The scientific participants left R/V POSEIDON at 11.00 p.m. and finally the charter period ended at that day.

4. Individual scientific reports and first results

4.1. Work Report of the Coral-Sponge-Habitat Mapping Team

(A. Freiwald, V. Hühnerbach, J. Campbell)

4.1.1 Introduction

Coral reefs are something we usually associate with warm, tropical waters, but not with cold, deep and dark waters of the North Atlantic. It is now known that cold-water coral species also produce reefs which rival their tropical counterparts in terms of their species richness and diversity. Increasing commercial operations in deep waters, and the use of advanced offshore technology have slowly revealed the true extent of Europe's hidden coral ecosystems. In the Northeast Atlantic, the geographic distribution of deeper water coral ecosystems can be traced from the slopes and banks off the Iberian Peninsula as far north as to the Scandinavian Shelf and must be regarded as a primary biological ressource for present and future sustainable use. Of special relevance for the BOSMAN-project is the high taxonomic diversity of sponges which are associated with the coral reef tracts but which occur more spectacular in the near off-reef vicinity.

4.1.2 *Lophelia*-occurrences in Scandinavian shelf and fjord settings

In Scandinavian waters *Lophelia pertusa* is present in the Skagerrak where its easternmost occurrences reaches the Swedish Bohuslän coast, Oslofjord, and along the Norwegian coastline up to the West-Finnmark District, northern Norway (Fig. 4.1-1.). The inner shelf and deep fjords of the Finnmark District mark the northernmost limit of *Lophelia pertusa* at 70° northern latitude (DONS, 1944; FREIWALD et al., 1997; HOVLAND & MORTENSEN, 1999).

Topographic and oceanographic background

The Norwegian Shelf is characterized by a series of shallow banks which are dissected by deep troughs (HOLTEDAHL, 1940). The Norwegian shelf is bathed in a surface water mass, the Norwegian Coastal Current (NCC), while the oceanic North Atlantic Current (NAC) water is fenced off from the shelf (HELLAND-HANSEN and NANSEN, 1909; MORK, 1981). The NCC water has salinities of less than 35 ‰ while the NAC water has salinities of >35 ‰ (EIDE, 1979). The important exceptions are the deep glacially-eroded troughs which act as conduits for the more dense NAC water (Fig. 4.1-2; LJØEN and NAKKEN, 1969). These shelf troughs continue as deep fjords into the Caledonian hinterland. These topographically-guided branches of the dense

and more saline NAC underflow the less saline NCC water that occupies the shelf banks and fjords (LJØEN and NAKKEN, 1969). Norwegian fjords which experience periodic renewal of NAC water intrusions, the occurrence of *Lophelia* is to be expected (DONS, 1944; BURDON-JONES and TAMBS-LYCHE, 1960; FREIWALD et al., 1997).

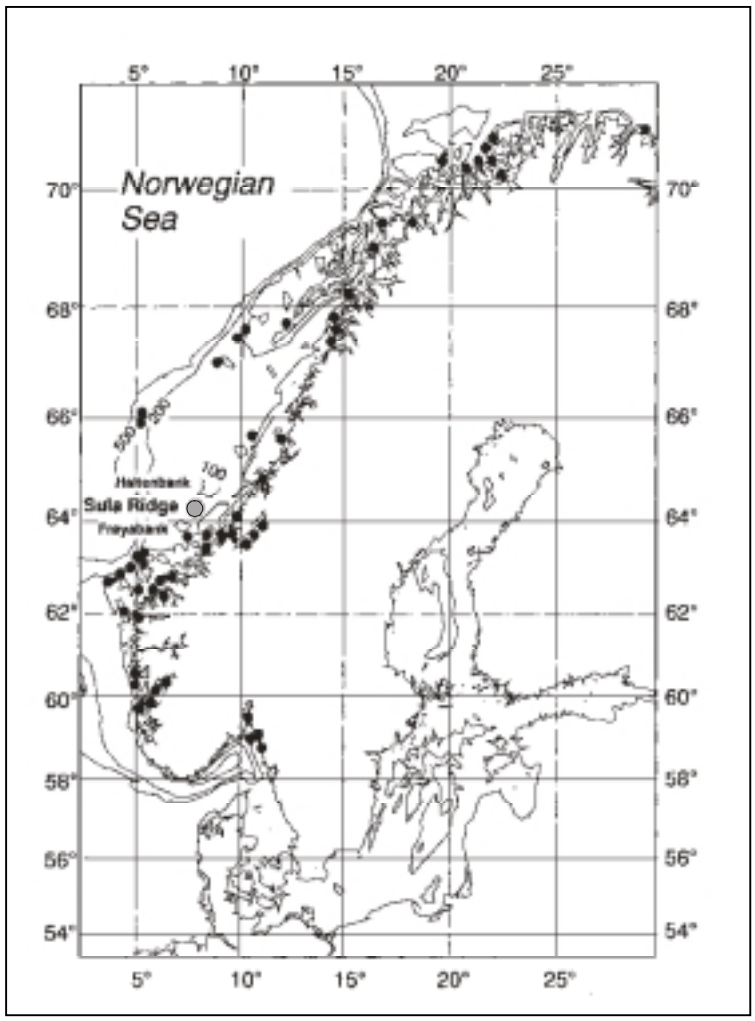


Fig. 4.1-1. Distribution of *Lophelia pertusa* occurrences in Scandinavian waters (black dots). The BOSMAN-Site on the Sula Ridge is located on the mid-Norwegian Shelf in 250 - 300m water depth (modified from FREIWALD, 1998).

POS-254 study site: Sula Ridge

The Norwegian shelf off the Trondelag District is characterised by two shallow banks, the Frøyabank to the south and the Haltenbank to the north (Fig. 4.1-2.). A pronounced seafloor depression separates these two bank areas. The broad and even Egga Basin merges into the continental margin which is affected by giant slope failures — the Storegga slide events (JANSEN et al., 1987; BUGGE et al., 1988). To the east, a threshold at 290 m water depth, the Frøya Ridge, separates the Egga Basin from the Haltendjup Basin. The latter forms a depression which is up to 540 m deep and is oriented parallel to the coastline, and which encircles the eastern margin of the Haltenbank.

The southern end of the Haltenbankdjup depression is intersected by a spur — the Sula Ridge (Fig. 4.1-2.). As a morphological elongation of the Frøyabank, this ridge forms a northeast-plunging spur at 250 to 320 m water depth. The Sula Ridge is bordered by morphological depressions which are around 340 m deep. The complex morphology between the Frøya- and Haltenbank area results from the different erosive resistance of the underlying bedrock to the abrasive forces of waning and waxing Pleistocene glaciers. While the depressions are underlain by more easily erodible sedimentary rocks of Meso- and Cenozoic age, the two ridges consist of more competent Paleocene (Sula Ridge) and Oligocene (Frøya Ridge) deposits (BUGGE et al., 1984).

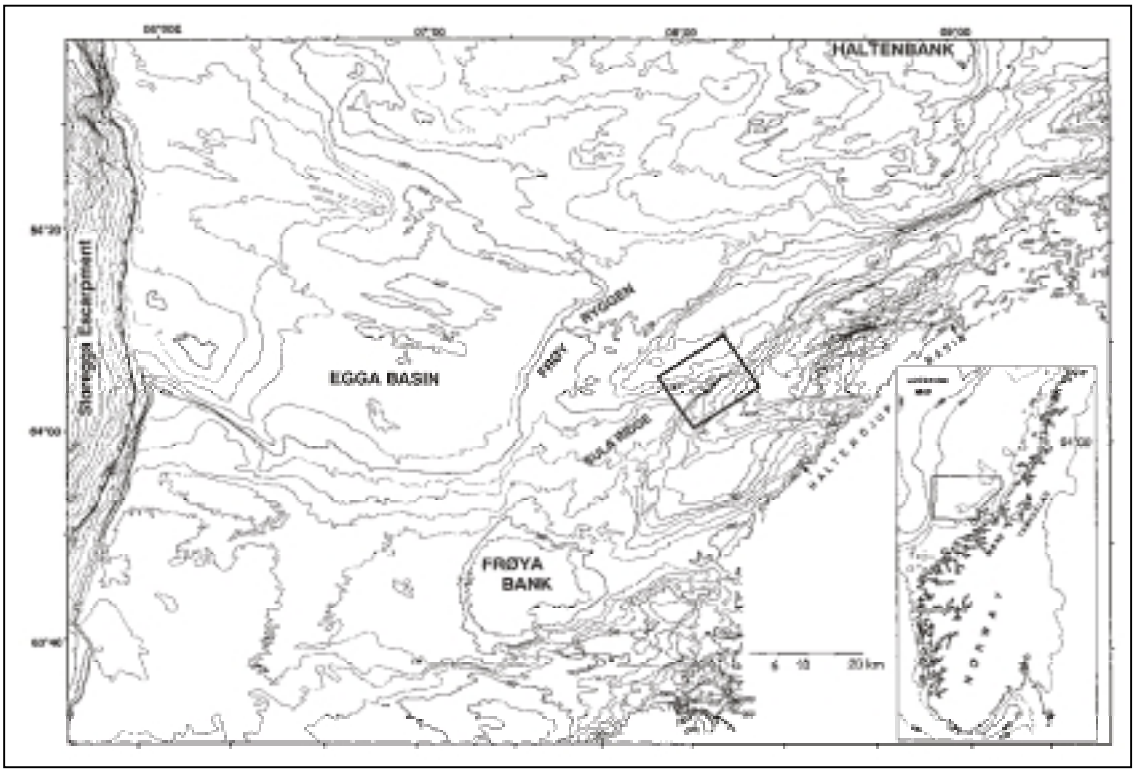


Fig. 4.1-2. Bathymetric map of the mid-Norwegian Shelf sector (see insert map). The BOSMAN-Site is indicated (rectangle; modified from HOLTEDAHL and BJERKLI, 1982).

Focusing on the Sula Ridge, the western flank of the Paleocene bedrock structure is covered by the Haltenbank moraine which was formed during the last ice advance on the shelf shortly before 12,000 yrs B.P. (BUGGE, 1980). In general, Quarternary sediments form a thin (<50 m) and discontinuous cover on the inner shelf and thick (100 - 350 m) accumulations towards the shelf margin (KING et al., 1991; HAFLIDASON et al., 1991). During the disintegration of the Fennoscandian iceshield, the Norwegian shelf was prone to intense iceberg scouring on the sea-floor. The iceberg ploughmarks have widths of up to 100 m and depths of up to 10 m (LIEN, 1983a, b).

On the Sula Ridge, the grounded icebergs created levees which predominantly consist of abraded Paleocene sand- and claystone blocks (FREIWALD et al., 1999). In the close vicinity to the Sula Ridge, pockmark fields occur in the morphological depressions which are covered by muddy sediments (HOVLAND et al., 1998). These pockmarks are fed by emanating porewaters and gases from hydrocarbon reservoirs beneath. By analogy with dense biotic accumulations found around hot vents (CHILDRESS et al., 1986; BROOKS et al., 1987) and in cold seep areas (HOVLAND and THOMSEN, 1989), the distribution patterns of *Lophelia pertusa* are also considered to be controlled by hydrocarbon seepage (HOVLAND, 1990; HOVLAND et al., 1994; HOVLAND et al., 1998). However, seep-controlled benthic communities like those from the Skagerrak location are rather different in species composition than the coral-dominated systems. There is much stronger evidence for the bentho-pelagic coupling mode that, in concert with the year-round stable temperature and salinity conditions open the ecologic window for *Lophelia pertusa* on the Sula Ridge and elsewhere in Scandinavian waters.

As stated earlier, the Sula Ridge area is located in the path of a topographically-guided tongue of NAC water which is intruding onto the mid-Norwegian shelf between Frøya- and Haltenbank.

Seafloor topography and sedimentary facies on the Sula Ridge

The seafloor on the Sula Ridge in the studied sector is highly variable in both its topographic features and the sedimentary facies. The ridge forms an elongated, northeast-southwest oriented spur. Measurements made of the portion above 300 m water depth, the ridge was shown to be 6300 m wide at the southwestern end. Following the ridge towards the northeast over a distance of 18 km, the <300 m-portion narrows to 400 m in width (Fig. 4.1-2). Echosounding transects, which crossed the ridge perpendicular to the long axis exhibit the asymmetric shape of the Sula Ridge. In general, the northwesterly margin forms a gentle downsloping flank to 350 m water depth. The opposing southeastern margin is represented by a 30 - 70 m deep escarpment which slopes steeply down to water depths greater than 380 m. This escarpment marks the lithological boundary between the rigid Paleocene sand- and claystones which form the backbone of the Sula Ridge and the more erodible Cretaceous claystones (BUGGE et al., 1984).

Aside from the coral reefs, the sedimentary facies on the Sula Ridge is largely influenced by the Late Pleistocene glaciomarine depositional regime (HOLTEDAHL and BJERKLI, 1982). The visual inspections and grab samples demonstrated the presence of pelitic sand bottoms with carbonate contents of less than 3 % in water depths >300 m. The sedimentary structures are dominated by abundant craters of crustacean burrows formed by *Munida sarsi*. Ice-rafted boulders occur sporadically in the pelitic sand facies. These boulders serve as 'rocky-island' substrates for sponges, bryozoans, ascidians, hydroids and brachiopods. Along the northwestern slope of the Sula Ridge several low-relief sediment drifts were mapped in 300-320 m water depth with the side-scan sonar in 1995 (RV Victor Hensen Cruise 24/95). The drifts pass the ridge in a nearly west to east direction. However, it is not known if these rippled areas are active structures or are moribund. Pebbly sand patches with winnowed subfossil *Mya truncata* and *Hiatella arctica* shells and valves are present in water depths shallower than 300 m. The pebbles have a polymict composition. This sediment is thought to represent a till probably belonging to the Haltenbank moraine which was colonized by the infaunal bivalves after the retreat of the ice (HOLTEDAHL et al. 1974; BUGGE, 1980).

The most prominent sedimentary structures on the Sula Ridge are iceberg ploughmarks (IPM). The northwestern gently sloping flank of the ridge is heavily scoured by IPMs which increase in numbers towards the summit. According to the sonographs, two generations of IPMs are discernible (FREIWALD et al., 1999). The older generation was scoured by icebergs which drift more or less parallel to the ridge, from southwest to northeast. These IPMs are cut by icebergs which cross the Sula Ridge in a west to east direction. It is most likely, that the deep-rooted icebergs were picked up by currents that followed the morphological depression through the Egga Basin into the Haltendjup Basin. The boulder levees which are up to 5 m in height are predominantly formed by abraded blocks from the Paleocene sand- and claystone basement.

4.1.3 Habitat mapping during POS-254

The major scientific target for the cruise POS-254 was dedicated to retrieve high quality sponge samples from the seafloor for the sensitive detection and subsequent identification of marine natural compounds. In order to offer an economic method for the search of sponge-rich habitats within the very complex reef topography and to avoid unnecessary damage on the benthic communities, the following strategy was chosen:

1. Echosounding and side-scan-sonar mapping of a defined seafloor grid on Sula Ridge prefentially during night time.
2. Identification of sponge-rich target areas on the basis of the seafloor mapping surveys.
3. Occasional bottom sampling with a Van Veen grab and a dredge in precisely known *non*-reef locations. One of these random off-reef bottom samples yielded the first occurrence of the scleractinian *Stenocyathus vermiformis* (FREIWALD & MORTENSEN, subm.).
4. Dives with the manned research submersible JAGO for groundtruthing of the acoustically mapped areas by video and still camera documentation and for sampling of relevant fauna.

Echosounding surveys

The Sula Ridge was mapped sector by sector using a narrow-beam 30-kHz and an 18-kHz echosounder with DGPS navigational support. A narrow sounding grid (lines 388, 390, 392, 397 - 405, 423 - 426) was surveyed in the northeastern part of the ridge.

The mapped coral reef structure has a total length of 13 km and a width of 150 to 300 m. Average framework thickness is 10 m but up to 35 m high build ups were crossed (Fig. 4.1-3). In addition, the ship-based facilities allowed online recording and logging of the ships track, coordinates and water depth to create a contour map (Fig. 4.1-4). A high resolution contour map with combined data sets from POS-228 (HENRICH & FREIWALD, 1997) is in progress.

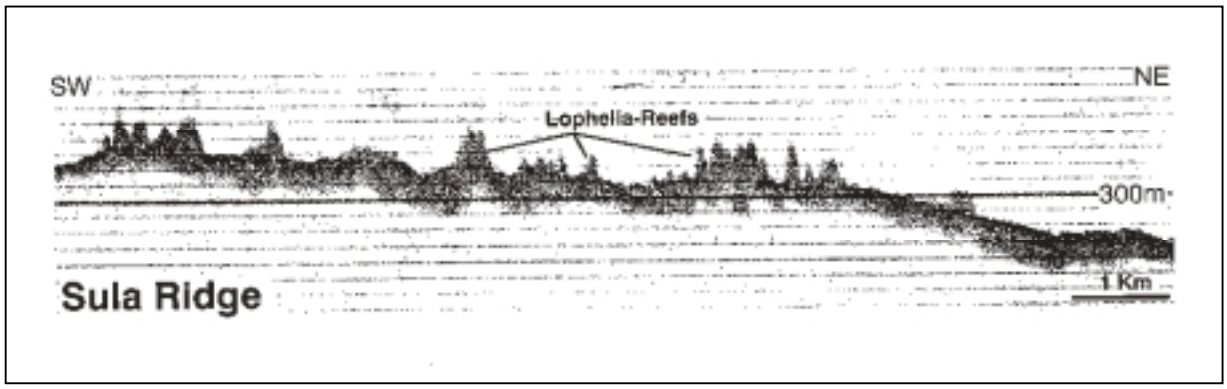


Fig. 4.1-3. Dense development of *Lophelia* reefs recorded along the Sula Ridge central part (echosound log).

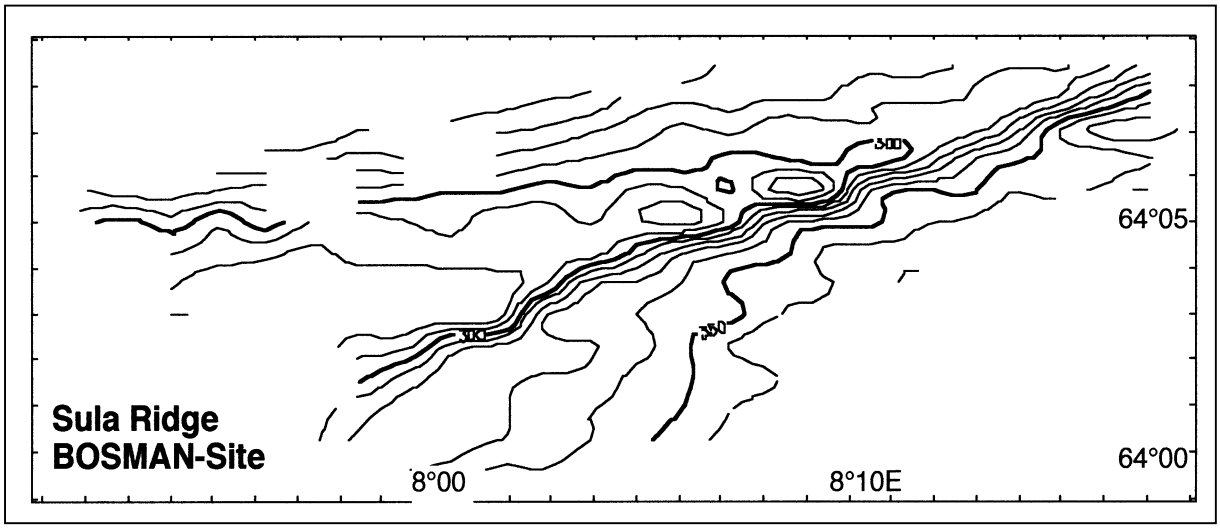


Fig. 4.1-4. Contour map of the BOSMAN working area on the northeastern Sula ridge.

Sidescan sonar operations

The shallow water sidescan equipment used was an Ultra Electronics Model 3050E Widescan with a digital logging system. It is an lightweight dual frequency (100/325kHz) high-resolution system capable of operations down to 300m water depth. The standard system provided by the Southampton Oceanographic Centre (SOC) consists of a sidescan sonar towfish, a Signal Processing Unit with basic image correction and gain control and a 12 inch thermal chart paper recorder (Fig. 4.1-5). The SOC system is modified to allow full digital raw data acquisition for onbord and post-cruise 'state-of-the-art' image processing using PRISM software suite, developed at SOC.

All sidescan data were recorded online digitally on a PC harddisk as well as paper printout. Navigation data were collected with a FURUNO DGPS system located onboard and also stored on the PC. During the last part of the sonar survey a new acquisition system with real-time display on a monitor was tested.

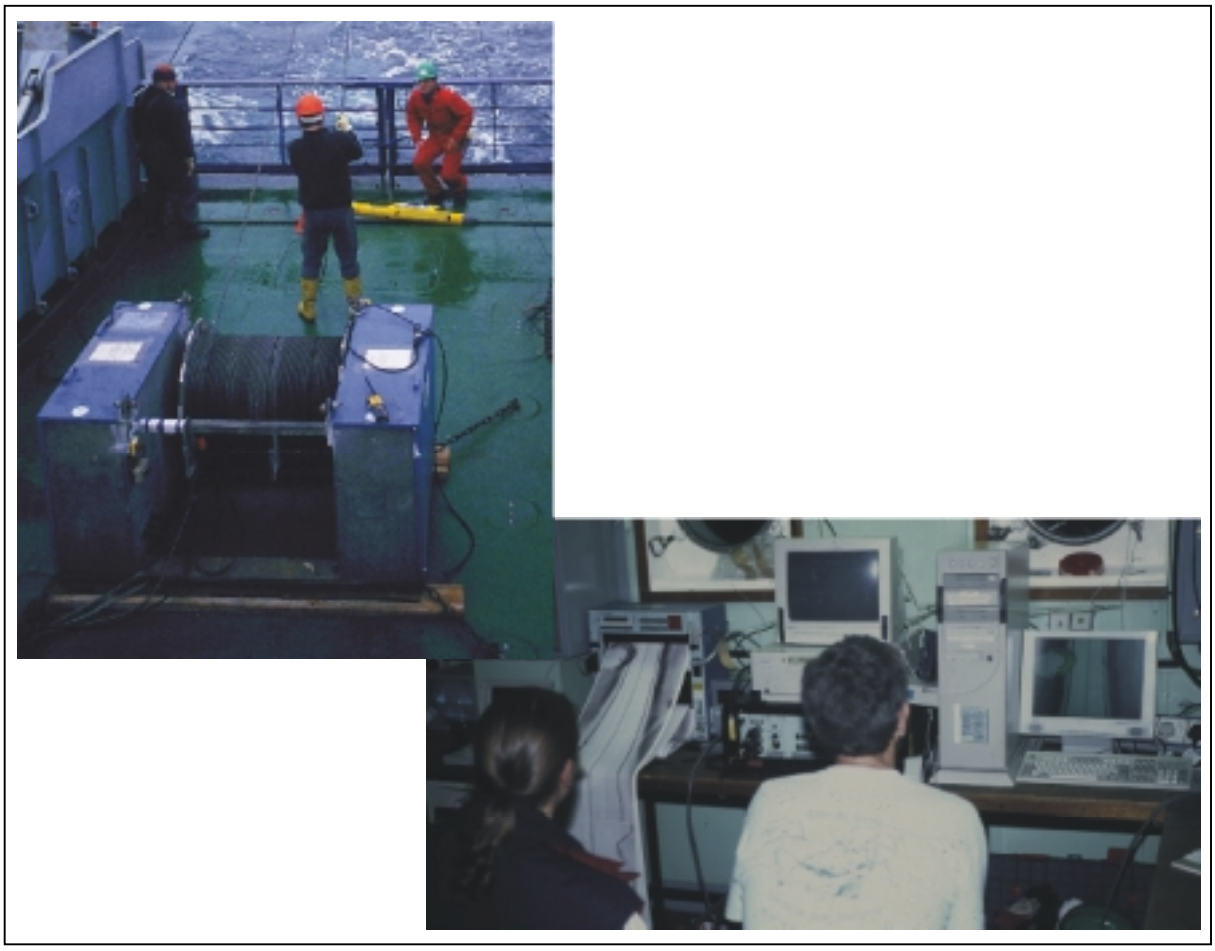


Fig. 4.1-5. Side scan sonar lab hardware installation during POS-254 showing analog (left) and digital (right) logging facilities.

Winch

The winch used for this survey was a 3-phase electric oceanographic winch (380V/4kW) from SEATRONICS Ltd. with remote control, cable counter and 1000m double armoured coaxial conducting cable (Fig. 4.1-5).

The connection between sonar acquisition unit in the lab and the winch (with Sidescan sonar fish) was done with a 100m lightweight Kevlar cable.

A remote control on the winch allowed the operator to keep an eye on the online display at the same time as hauling in or paying out cable. The maximum payout was 900m for a water depth of approximately 320m because no depressor weight was used to get the towfish sufficiently close (10-15% of the survey range used) to the seabed. Maximum speed for hauling and payout was up tp 1m/s.

In the evening of the 30th July sidescan survey had to be stopped due to a slip-ring fault on the winch side. In the course of this a new cable termination had to be made, which resulted in a data gap of 24 hours.

Sidescan sonar survey

The survey carried out during this cruise was designed to cover the area of the Sula-Ridge in the time available. Following a detailled reconnaissance of existing data it was decided that lines along the reef axis with a total swath of 400m and a spacing of 100m would provide a full sonar coverage of the ridge. The overlap of 75% should eliminate possible gaps in coverage caused by drift of the sidescan due to currents from the side and errors in navigation (Figs. 4.1-6 - 7).

The frequency used for the main survey was 100kHz with a long pulse to allow maximum swath width.

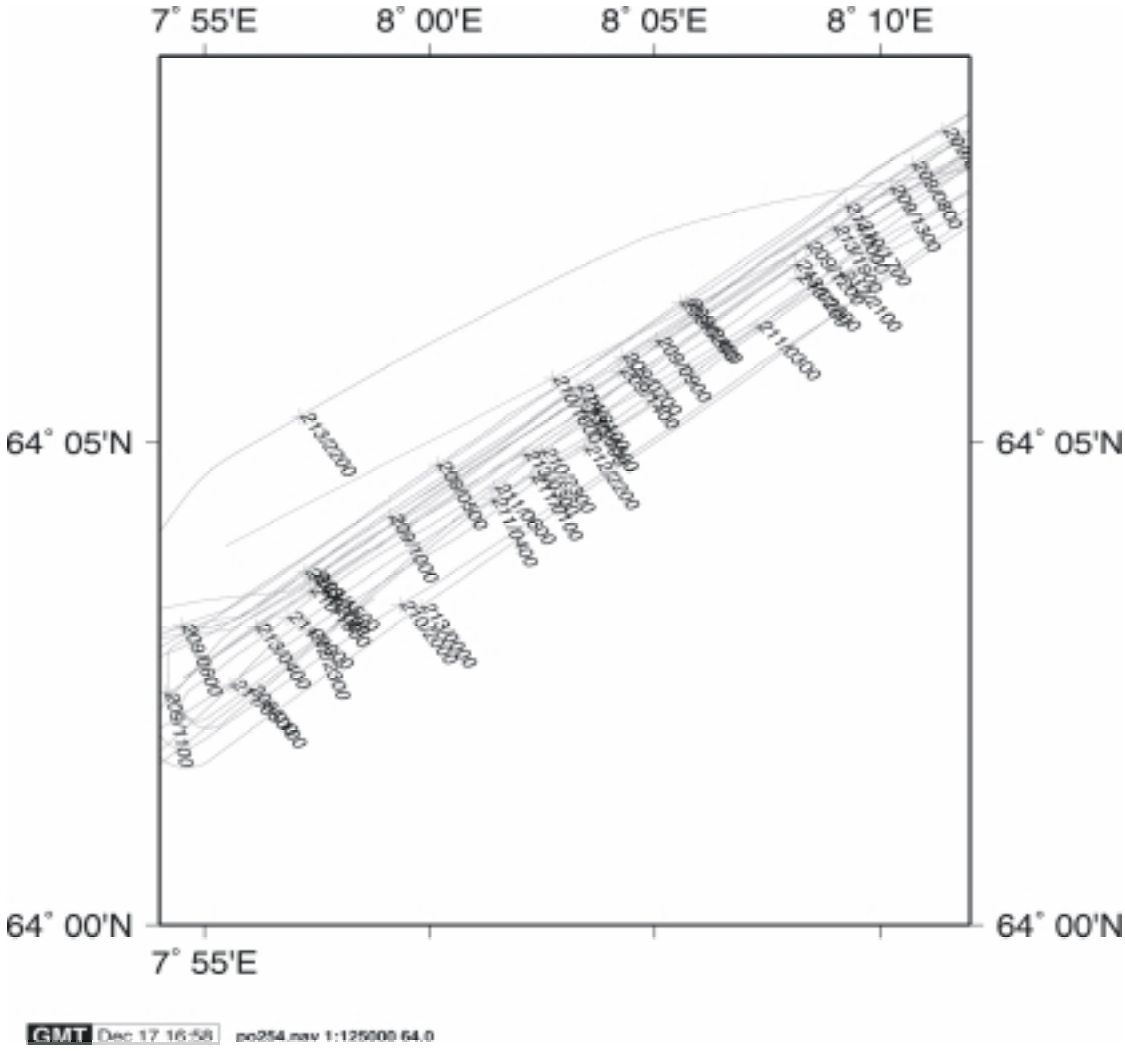


Fig. 4.1-6. Tracklines of the side-scan sonar survey in the BOSMAN working area.

The sidescan surveys were carried out at night when the submersible batteries were recharged. From these surveys the new diving positions were derived. In total 140 km of tracks were run in 10 lines, covering an area of approximately 11 km^2. All

survey tracks were designed to run from NE to SW against a slight current. The ship speed during the sidescan recordings was relatively constant at 3-3.5 knots.

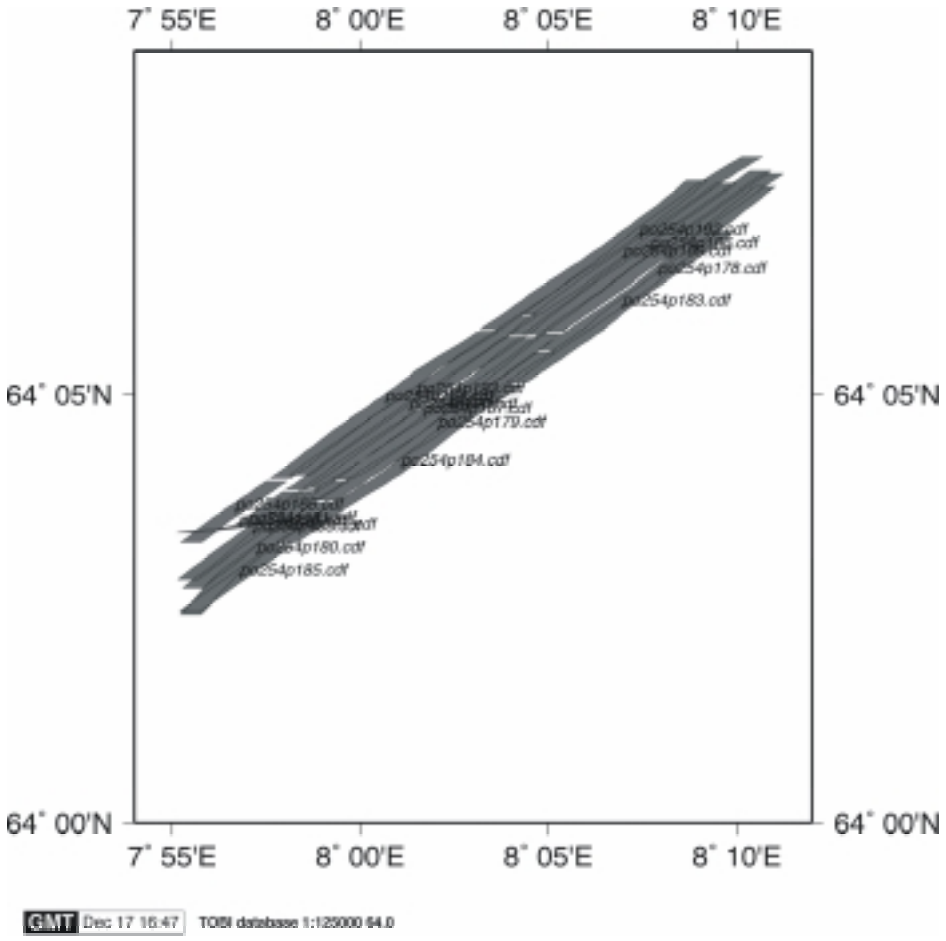


Fig. 4.1-7. Areal coverage map of acoustically surveyed seafloor on Sula Ridge.

In order to save time at the end of each sonar line the system was not recovered, but brought up to a safe height (cable out set to less than the minimum water depth) to allow the ship to steam back at 6.5 knots to the beginning of the next line. During the survey and the transit lines the ship's echosounder provided substantial bathymetrical information of the reef for the sonar operators 'flying' the towfish.

On the first 4 lines data were influenced by a 2-3m high swell which caused the towfish to roll and pitch slightly because the fish was not decoupled from the winch cable. Therefore surveytracks 2-4 were repeated during the second half of the cruise when the seastate improved significantly.

On the last day the repetition of line 1 could not be continued/done due to fishing activity next to the reef; as an alternative 3 sidescan lines crossing the northern part of the ridge were chosen. During these lines the new sonar acquisition system was

tested. The digital data were recorded using the high (325kHz) frequency with a 75m range. The lengths of this lines, with course SSW/NNE, were 4 km each.

First results

The full extent of the coral reef chain on the Sula-Ridge was covered with high-resolution sidescan imagery. The sonographs clearly show the limits of the reef structure (Fig. 4.1-8). The northwestern and western part of the reef shows a light grey backscatter indicating a relatively smooth seafloor with probably fine-grained sediment and iceberg ploughmarks of various sizes. Compared to this the central and southern area show more backscatter variation - from white (coral patches/high backscatter) to black (shadow zones/low backscatter).

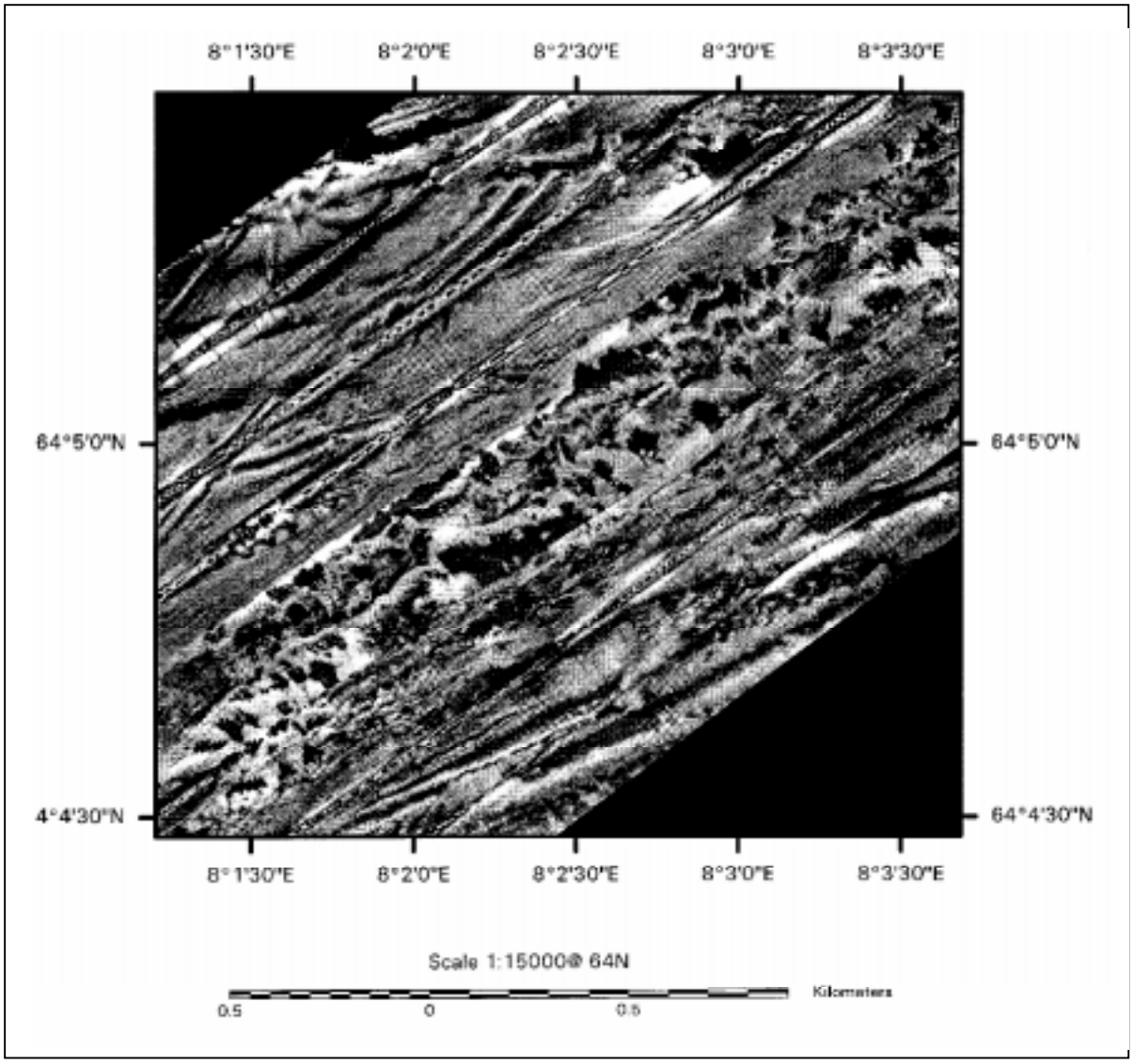


Fig. 4.1-8. Side scan sonar map with *Lophelia* reefs (rough areas) and iceberg-plough marks (elongated structures) of the central section of the Sula Ridge.

Distribution of Lophelia reefs on the Sula Ridge

On the Sula Ridge, the bathymetric range for the *Lophelia* reefs is from 330 - 233 m water depth. The reefs are concentrated along the summit near the escarpment of the asymmetric Sula Ridge. The length of the main *Lophelia* reef complex on the Sula Ridge is approximately 13 km (FREIWALD et al., 1999). Further south on the ridge near the transition into the Frøyabank, another group of more isolated reefs have been studied by MORTENSEN et al. (1995) and HOVLAND et al. (1998). The reefs on the Sula Ridge are 10 - 20 m high on average. The maximum height — 35 m — was observed on a single reef complex.

Iceberg controlled reef geometry

The sonographs which were aquired with the deep-towed sidescan sonar along the strike line of the ridge allow the recognition of numerous individual 1 - 2 km long and 100 - 200 m wide reefs which often are arranged *en echelon*. Measurements carried out with the submersible confirmed the distinctive offset of 20° in the orientation of the reefs in relation to the northeast-southwest strike of the Sula Ridge (FREIWALD et al., 1999). The reason for this offset in the orientation of the individual reefs becomes discernible at the western limits of the reefs and along the gently downsloping northwestern flank of the Sula Ridge. The corals can be seen to grow on the ridge and furrow systems which were produced by grounding icebergs (FREIWALD et al., 1999). Immature stages of reef growth are less than 10 m high and show parallel rows of coral colonies on the opposing boulder levees. In more mature stages, the furrow between the levees is filled up by metre-sized chunks of dead *Lophelia* which, in turn, are recolonized by 1 - 3 m high hemispheroidal coral colonies, the coppices, which form the distinctive 'cauliflower' images on the sonographs. The final stage of the development of the reef occurs when the offset colonies coalesce along the ridge forming the maximum coral growth along the northeast-trending top of the ridge.

A distinctive pattern of low-relief coral debris mounds are located due west of the main coral reef chain. These 3 - 8 m high seafloor elevations have a circular outline and consist of broken *Lophelia* debris. A detailed interpretation of the area, including a distribution of coral patches, will be drawn up from the processed sonar imagery (Fig. 4.1-9).

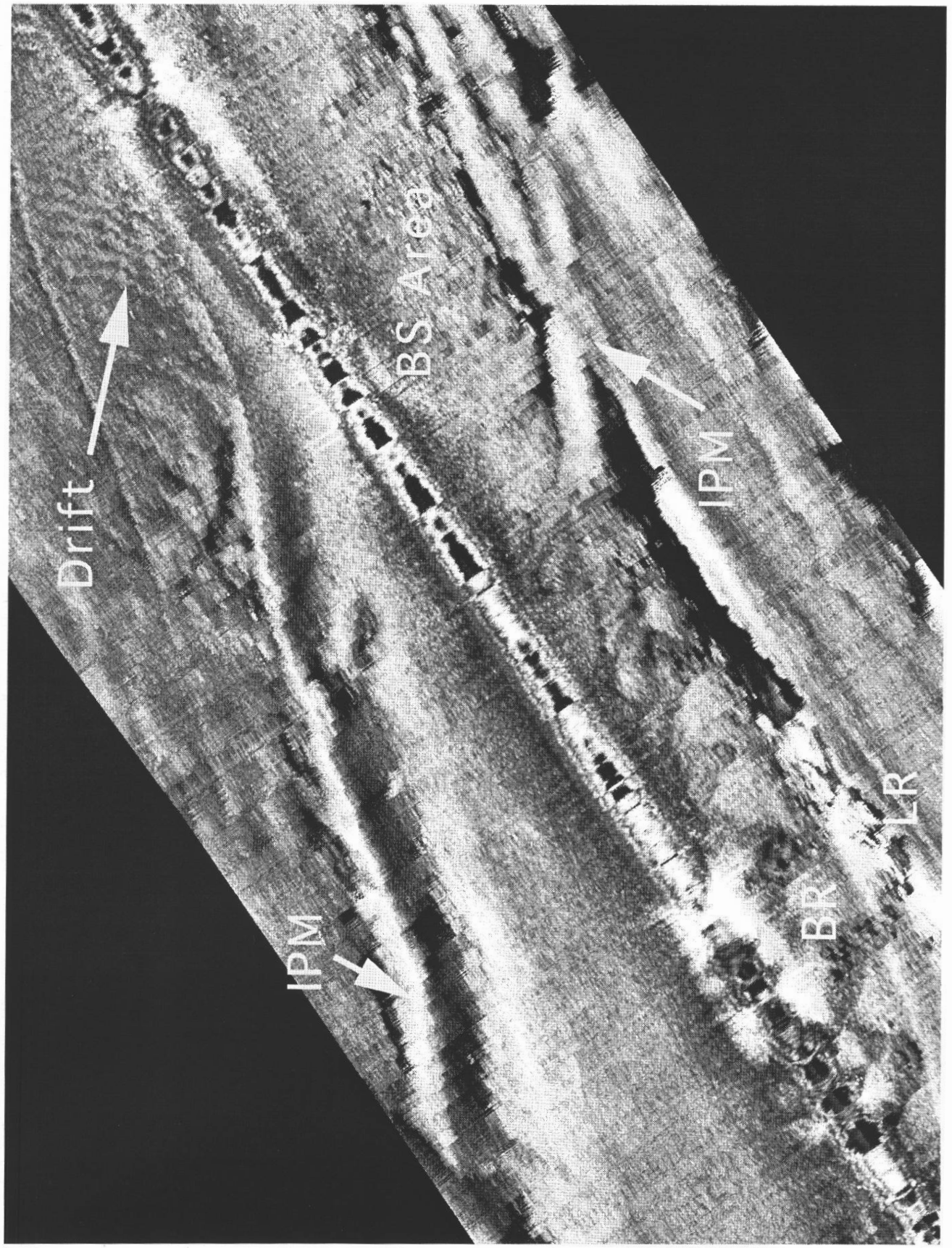


Fig. 4.1-9. Close-up of digitzed side scan sonar map showing different seafloor habitats: IPM (Iceberg-Ploughmarks), sediment drift, LR (living *Lophelia* reefs), BR (dead (buried) *Lophelia* reefs, rich in sponges), BS Area (Boulder and sand area rich in sponges).

4.1.4 Grab sampling

During a high swell period on Sula Ridge, a 50kg Van Veen grab was used in order to collect sponges from sidescan sonar identified boulder fields. A total of 10 grabs (stations 406 - 415) retrieved pebbly sediment pavements which are underlain by a sandy-silty glacio-marine deposit with dispersed pebbles. The shelly fauna was almost subfossil and consist of heavily corroded *Chlamys islandica,* thick-shelled *Hiatella arctica*, scaphopods and large fenestellid bryozoan fans. The exposed pebbles were colonized by *Terebratulina retusa* (Brachiopoda), benthic foraminifers, predominantly *Cibicides lobatulus* and *Dorothia rudis*. Sponges occur quite common as colonizers, however, after the grabbing procedure, the quality of the sponge tissue rarely reached the suitable standards for the marine natural product studies. A highlight was the first discovery of a live *Stenocyathus vermiformis* in Norwegian waters (station 412 at 276m water depth). This is the third scleractinian species existing on Sula Ridge (FREIWALD & MORTENSEN, subm.).

4.1.5 Dredge sampling

During the same poor weather period, a dredge with an rectangular aperture was used in an off-reef boulder field (station 394) and near the foot of a coral rubble mound which was known from POS-228 (station 395). It should be pointed out clearly, that dredging within the live coral reefs has to be prevented by all means. Only with our existing maps at hand, we were able to avoid damage to the corals. The anticipated sponges from the two dredge hauls were rich but were — as usual — severely destroyed or clogged with sediment and therefore did not meet the BOSMAN sampling standards.

4.1.6 Dives with the manned submersible JAGO

The JAGO is one of the most efficient manned submersibles for offshore shelf research down to 400m water depth. The submersible offers two seats, one for the pilot and the other for a scientist. The frontal window permits a undistorted view of the scenery in front which can be illuminated with a large set of bulbs for various purposes (Fig. 4.1-10). Photographic documentation is handled with a Nikon camera from inside the submersible with two flashbulbs outside. Sampling is performed with a hydraulic manipulator for bottom samples and by an 5l-Niskin water sampler. The samples were stored in a box with different tubes (partly with a lid) for the sponges.

Continuous video documentation is performed with a Panasonic digital camera. With its total weight of 3033kg all medium-sized vessels with a crane-lift capacity of about 5 tons are suited for JAGO operations. Water temperature, depth and heading are indicated. The communication between JAGO and POSEIDON was secured by an hydrophone. JAGO operated on Sula Ridge first time in 1997 on POS-228 (HENRICH & FREIWALD, 1997). During POS-254, a total of 8 dives with two dives a day have been carried out. The diving operations lasted between 3 and 4 hours each. The maximum diving depth was 325m.

Fig. 4.1-10. The manned research submersible Jago, front view.

Operational notes

The submersible dives were carefully planned after the maps performed with the sidescan sonar. Therefore, all dive sites stayed inside the sonographed grid. Navigation at the seafloor was possible with a special ship-based navigation system which controlled JAGO's position permanently. For locating distinct targets, JAGO was guided via hydrophone communication from POSEIDON precisely. It is probably the first time to combine high quality sonographs of individual reef tracts with ground-truthed photo/video documents of the same object (work in progress)!

First results

A brief description of principal coral reef zonation and off-reef areas which derived from the JAGO dives are presented below.

Vertical zonation pattern of individual reefs

The *Lophelia* reefs generally are steeply flanked, sometimes even forming vertical slopes and overhangs. While smaller reefs tend to be oval or circular in outline, all the larger reef complexes are elongated. MORTENSEN et al. (1995) described three distinct zones from the isolated reefs on the southern Sula Ridge: (1) living *Lophelia*, (2) dead *Lophelia* and (3) *Lophelia* rubble. This vertical zonation pattern is principally the same as that observed on the main reef complex on the Sula Ridge.

The reef top and upper flanks

As has been outlined in the previous section, the reeftop often exhibits two parallel crest lines of living *Lophelia* coppices. These double-crested reefs grow on the opposing boulder levees of the IPMs. The shape of a healthy coppice is a circular or slightly elongated, hemispheroidal accumulation of bushy, dendroid coral colonies (Fig. 4.1-11A-B). The coppices which form the living rind of the reef measure 1.5 to 4 m in diameter and are up to 1.5 m thick. As has been postulated by WILSON (1979), at this size the core of the coppice generally is in the stage of degradation and gives way to what can be pragmatically described as a "WILSON Ring". The overwhelming mass of living *Lophelia* has colourless soft tissue and mucus slime. The living rind of the coppices is also developed along the upper flanks of the reef complex where predominantly elongated galleries or isolated, large and arborescent groups of colonies are found. Macroscopically only a few attached organisms thrive within the living coral rind. The most spectacular of these are the red or white fans of *Paragorgia arborea* (Fig. 4.1-11B).

The dead framework flanks

The steep sloping flanks are formed by dead and often exposed *Lophelia* framework (Fig. 4.1-11C-F). The framework itself consists of intact and *in situ* colonies or colonies which are slightly dislocated but kept in position. The most impressive accumulation of large but collapsed framework chunks is generally found in the gap between the parallel-lined crests of those reefs which grow on IPMs. The height of the dead coral framework zone varies considerably from less than 1 m to 20 m and forms the backbone of the reef complexes on Sula Ridge in terms of volume. The coral skeletons are intensely stained with iron-manganese and harbour a rich fauna which preferentially settled on biofilms. The lower third of the exposed flanks of the coral framework is clogged with silty muds but sediment-filled areas also exist

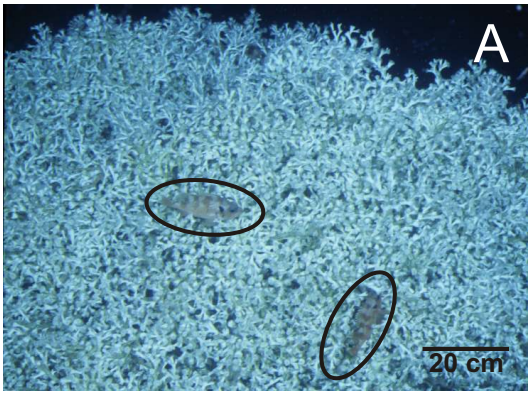
higher upslope in morphological depressions (Fig. 4.1-11D-F). The carbonate content of the infill is low — 3 to 10 % — but increases to 30 - 40 % higher upwards in the framework zone. The carbonate is contributed by coccolithophorids, planktonic foraminifers, *Aka* chips, spicules of octocorals and tunicates, benthic foraminifers, small gastropods and remains of crustaceans. The source of the terrigenous mud is external. Recolonisation by *Lophelia pertusa* in the dead framework zone occurs abundantly in the form of up to 8 m long and 1 m high coral galleries which can develop into coral-supported overhangs. The dominant competitors for space are, however, sponges.

The coral rubble aprons

Many individual reefs are fringed by 3 - 8 m high gentle sloping aprons (Fig. 4.1-11H) which have a bimodal sediment fill. Broken colony fragments of barely corroded *Lophelia pertusa* are embedded in a chaotic manner into sandy muds. The apron tops are apparently flat — like a terrace — and the characteristics of the sediment strongly resemble those of the low-relief coral debris mounds which occur some hundred metres west of the main reef complex (see below). Accumulations of *Acesta excavata* valves commonly occur on top of the flat aprons. The aprons are certainly fed by downfalling coral framework chunks but the impression is that they mostly represent remnants of the collapsed early stage of reef growth on Sula Ridge. Arguments in support of this hypothesis are: (1) the consistent height of the structures, (2) the terraced tops, (3) the infill of stratigraphically older deposits and (4) their occurrence as low-reliefed mounds off the main reef chain.

The coral debris mounds

A very apparent seafloor pattern are the numerous elevated mounds which have a circular outline and a thickness between 3 and 8 m. These structures have been identified first by the sidescan and were subsequently groundtruthed with JAGO. In detail, these mounds are of biogenic origin and represent in situ collapsed, dead *Lophelia* reefs which are completey clogged by sandy-silty sediments and — in many cases — overgrown by *Plakortis* sponges and others. These coral debris mounds show a characteristic smooth backscatter in comparison to the sharp backscatter of living *Lophelia* colonies (see also Fig. 4.1-9).


A
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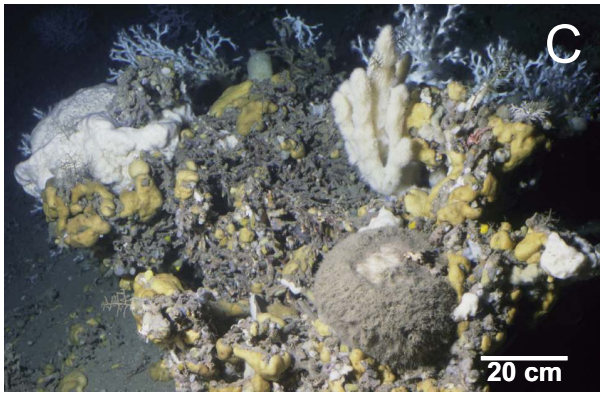
B
2
1
30 cm


C
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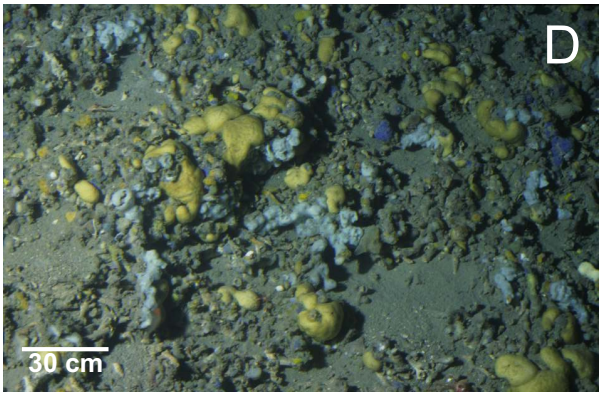
D
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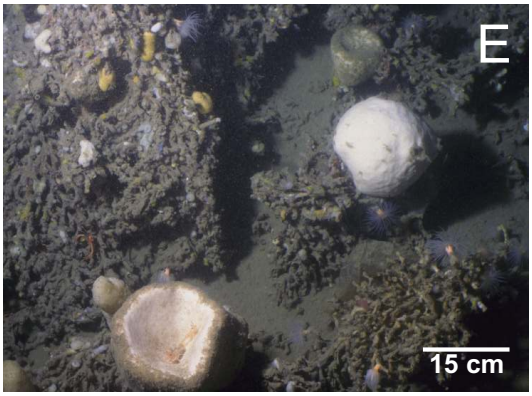
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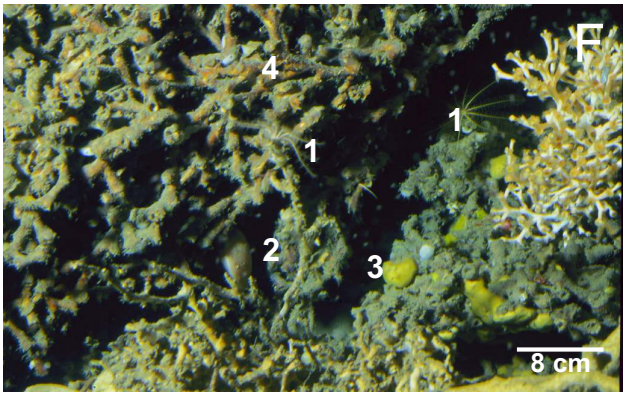
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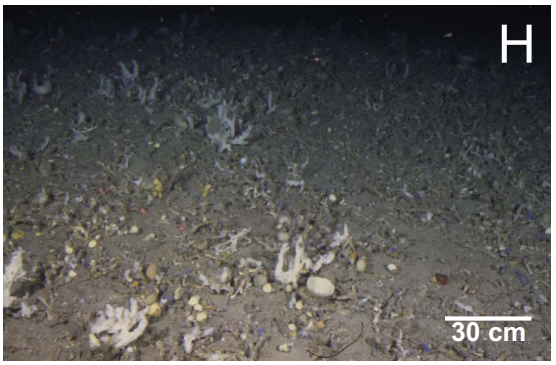
H
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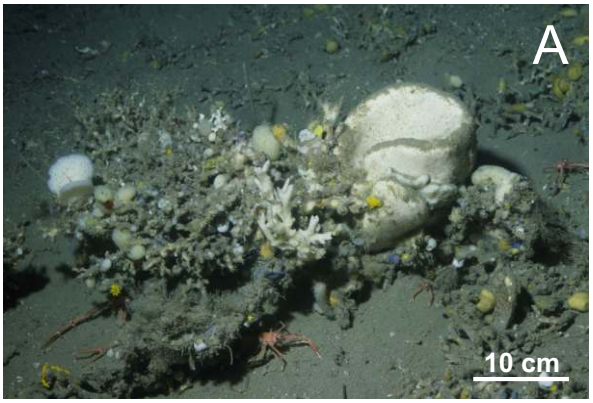
Fig. 4.1-11. (previous page). Jago photographs from the *Lophelia* reef. A) Living *Lophelia* colony with redfish *(Sebastes* sp.) hiding between the coral polyps. B) Single *Lophelia* colony surrounded by octocorals *(Primnoa resaedeformis* (1) and *Paragorgia arborea* (2). C) Dead *Lophelia* colony serve as a substrate for a diverse sponge assemblage. These sponges have been sampled by JAGO in detail. D) Reef base with sediment-clogged coral skeleton which is partly colonized by *Plakortis* sponges. E) Dislocated coral reef slabs with large sponges *(Pachastrella* at the forefront). F) Close-up showing aspects of colonisation of dead coral skeletons by: crinoids (1, *Antedon),* bivalves (2*, Acesta excavata),* sponges (3, *Plakortis),* microbial biofilm (4). G) Coral infestation by the parasitic foraminifer *Hyrrokkin sarcophaga*. H) Coral debris apron with diverse sponge colonisation.

The off-reef sand and boulder areas

Of special interest for the BOSMAN-project are the near-reef sand and boulder areas because of the high diversity of sponges. These sponge communities either are attached on the boulders as encrusters, sticky branching, chimney-like or cup-shaped specimens (Figs. 4.1-12). Few sponges live on and within the sediment (see REITNER, this report). The boulders mostly derived from the basement of Sula Ridge which became upwarped during the iceberg ploughing process. The exposed pebbles and cobbles from the sand flats generally are polymict in composition. They most likely derive from winnowing of Pleistocene glaciomarine deposits or arrived as ice-refted detritus on the seafloor.

Fig. 4.1-12. (next page). Characteristic sponge assemblages in degrading coral habitats (A-D) and in off-reef habitats (E-H) from Sula Ridge between 280 and 295 m water depth.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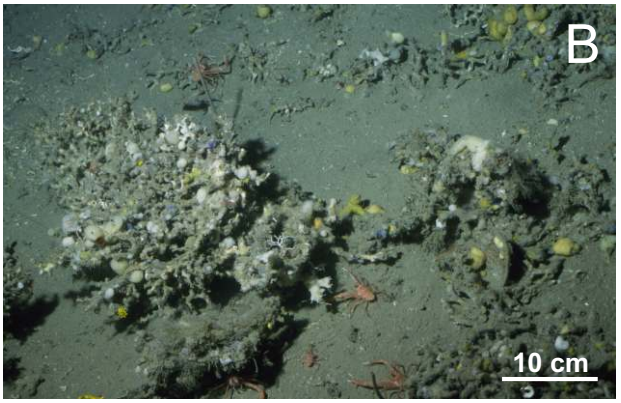
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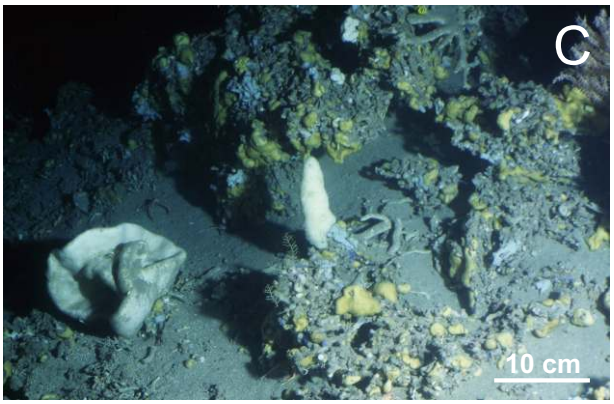
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D
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E
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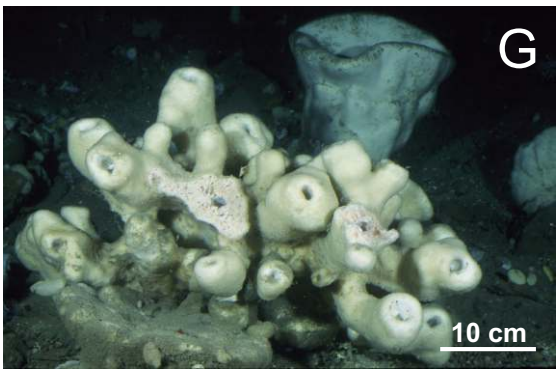
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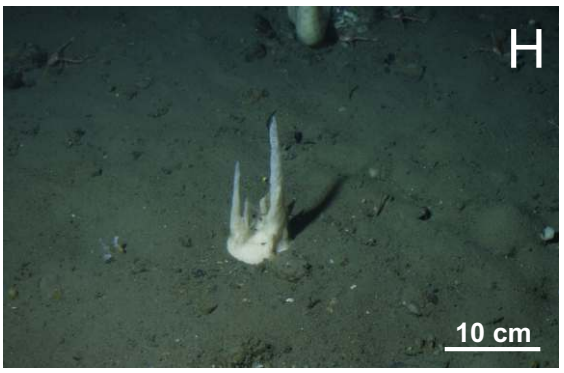
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4.2 Oceanography and Waterchemistry at Sula-Ridge *(T. Pape)*

4.2.1 Introduction

One main objective of the research programme BOSMAN is to study small scale environmental conditions of the deep water ecosystem, which influence occurence and concentrations of bioactive substances in sponges. Aside detailed video and photo documentations during JAGO dives for subsequent benthos mapping, numerous analyses of oceanographic and waterchemical parameters were carried out. Hydrocasts were performed at 8 stations of the reef area (Tab. 4.2-1.).

Station	Date	UTC	Latitude	Longitude	Water Depht [m]
01 MS	28/07/99	00:54	64:04:25N	08:01:50E	325
05 MS	28/07/99	19:54	64:05:00N	08:04:00E	332
16 MS	29/07/99	16:30	64:06:00N	08:03:00E	294
19 MS	30/07/99	15:38	64:05:90N	08:05:40E	286
23 MS	31/07/99	14:33	64:05:07N	08:06:50E	357
27 MS	01/08/99	12:00	64:04:25N	08:01:60E	322
31 MS	02/08/99	12:00	64:07:50N	08:09:50E	304
34 MS	03/08/99	05:24	64:03:20N	07:57:40E	273

Tab. 4.2-1. List of CTD stations

4.2.2 Instrumentation

Hydrocasts were carried out using a SEABIRD SBE 9 CTD, equipped with a rosette water sampler of 12 5-litre NISKIN bottles. The whole system was provided by the Institut für Meereskunde, Hamburg. The multiparameter probe measures pressure, temperature, conductivity, and oxygen saturation. Only the pressure, temperature, and conductivity sensors worked reliably. The data were monitored in real time (Scan Rate = 24 Hz) on a computer unit and have been averaged for 0,25 m distances.

4.2.3 Sampling and analytical methods

Water samples were taken during haulage of the CTD-Water-Sampling System. For receiving a dense physico-chemical data profile in the vicinity of the coral reef, predominantly water from depth below 200 m was sampled. Several samples, however, were taken from 0 - 200 m to characterize the general oceanographic situation. Additional sampling was done close to the reef by submersible using a 5-litre NISKIN bottle. At all, 73 samples were taken at 8 CTD- and 4 submersible-stations (an overview of all water sampling sites during POS 254 is given in Chapter 4.2.4).

Immediatly after recovery, samples for dissolved hydrocarbons (C_1-C_4), dissolved inorganic carbon, pH, dissolved oxygen, dissolved organic carbon, particulate organic material, and salinity were taken in a fixed order (Tab. 4.2-2.). At one selected station (26 JA) a watersample was taken for bacterial cultivation.

Station	hydrocarbons (C_1-C_4)	DIC	pH	Oxygen	DOC	Nutrients	POC	Salinity
01 MS		X	X	X				
05 MS	X	X	X	X	X	X		
16 MS		X	X	X	X	X	X	
18 JA	X	X		X	X	X		
19 MS	X	X	X	X	X	X	X	X
20 JA	X	X	X	X	X	X		X
23 MS	X	X	X	X	X	X	X	
27 MS	X	X	X	X	X	X		X
30 JA	X	X	X	X	X	X		
31 MS	X	X	X	X	X	X	X	X
32 JA	X	X		X	X	X		
34 MS	X	X	X	X	X	X		

Tab. 4.2-2. List of CTD (MS) and JAGO (JA) stations. X denotes stations where samples for the different parameters were taken.

All samples stored (except for measurements of salinity, nutrients and particulate organic carbon) were analyzed within 4 weeks after recovery. All chemicals used were per analytical- or Suprapur -grade and purchased from MERCK, Darmstadt.

pH

The pH measurements were carried out on board using a Schott pH-Meter (CG 841) equipped with an Ag/AgCl measuring electrode, an Ag/AgCl reference electrode and a temperature measuring bar. The electrodes were standardized daily using NBS Buffers (National Bureau of Standards) 4.00 and 7.00 (MERCK). All data were converted to *in situ* pH values.

Salinity

To calibrate the CTD data, selected water samples were collected for salinity measurements in the laboratory. In one case (20 JA), sampling was carried out during a dive to examine near-bottom salinity.

The samples were sealed airtight and stored in 100 mL glass bottles. Salinity measurements were performed by an autosalinometer at the Institut für Meereskunde, Hamburg.

PARTICULATES

Particulate organic carbon (POC)

In general, relatively large water volumes were necessary to obtain accurate concentration data. Thus, samples for analysis of POC were taken only at few stations, filling several Niskin-bottles at same water depths. It was attempted to take at least 7 L per sample to receive sufficient particulate material.

Samples from 4 stations were filled into plastic bottles and subsequently passed through glass microfibre filters (Whatman GF/F, 47 mm) by low pressure (200 mbar). The filters were rinsed with approximately 100 mL of Millipore water to remove salt, dried (30° C), and stored in plastic boxes until analysis.

Measurements of POC are not carried out until now.

NUTRIENTS

Samples for analyses of specific nutrients and the determination of DOC were taken at nearly all stations (except station 01 MS) in 250 mL gastight glass bottles and filtered by low pressure through glas microfibre filters (Whatman GF/F, 35mm). Subsamples for nutrient analyses were poisened with $HgCl_2$ and stored at 4 °C in 50 mL plastic bottles.

Nutrients (silicate, phosphate, nitrate, nitrite and ammonia) were determined with an autoanalyzer (Auto Analyzer 2, Technicon) at the Institut für Organische Chemie, Abteilung für Organo-Meereschemie, Hamburg.

DISSOLVED CARBON SPECIES

Dissolved organic carbon (DOC)

Aliquots of the filtrate for DOC measurements were taken in precombusted 20 mL ampoules and acidified with 50 % H_3PO_4 to a pH < 2.

Concentrations of DOC were measured at our laboratory using an automated Dimatec system (DIMA-TOC 100). Before analysis, inorganic carbon is removed by stripping the acidified samples with N_2. DOC is then converted to CO_2 by high temperature catalytic (850 °C, platinum catalyst) oxidation and measured by infrared detection. The system is calibrated with standard solutions (potassium hydrogen phthalate) of DOC concentrations usually occuring in ocean waters. The precision of DOC measurements is estimated to be $\pm$ 10 µmol kg^{-1}.

Dissolved inorganic carbon (DIC)

Samples for determination of DIC were filled in 250 mL glass bottles, poisoned with $HgCl_2$, sealed airtight and stored.

Analyses were performed coulometrically (U.I.C. Inc., USA, model 5011) using the method after Johnson et al., 1985; Johnson and Sieburth, 1987; Johnson et al., 1993 and DOE, 1994. A defined sample volume is acidified with 8,5 % H_3PO_4 and stripped with N_2. The degassing CO_2 is dried by a moisture trap and conducted into the titration cell, where it forms a weak acid with the cathode solution. An indicator (thymolphtalein) leads to a change of colour (and transmission) of the cathode solution in dependence on pH (blue at pH 10,5 and clear at pH 9,3).

Changes in transmission values automatically activate the cell current and induce a back reaction to the initial transmission values, recorded as mV readings. These readings are equivalent to the CO_2 concentration of the sample. Reference standards from A. Dickson (Scripps Institution of Oceanography, San Diego, USA) were used to calibrate the system at a precision of $\pm$ 5 µmol kg^{-1} seawater.

DISSOLVED GASES

Light dissolved hydrocarbons

Samples for analysis of methane and C_2 - C_4 hydrocarbons were filled in 250 ml gastight glass bottles and stored at 4° C for subsequent analysis. For preservation of volatile hydrocarbons approximately 8 g NaOH pellets were added (Iversen, pers. comm.).

Light dissolved hydrocarbons were analysed in the laboratory applying a technique modified after Swinnerton and Linnenbom (1967), which is based on a purge and trap system (Michaelis et al., 1990). The analytical apparatus consists of two units, the stripping and trapping system (1) and the analytical and detection system (2).

(1) 200 mL of each sample are flushed by an inert carrier gas (precleaned He) from the gastight and head space free sample bottle into a purge vial, wherein the sample is stripped by He for about 30 min. The outflowing gas stream is dried ($Mg(ClO_4)_2$) and subsequently hydrocarbons are adsorbed on two cooled traps at - 80°C. The first trap, filled with Al_2O_3, holds back all hydrocarbons except methane ($\geq C_2$). Methane is adsorbed on the second trap, filled with activated charcoal. The trapped gases are released by heating of the traps to + 80°C and carried to unit 2.

(2) A gaschromatograph (CARLO ERBA, GC 6000) equipped with a packed (activated Al_2O_3) stainless steel column (approx. 3 m) and a flame ionisation detector (FID) was used to separate, detect and quantify individual components. GC temperature was 140° C, carrier gas: He. Recording and calculation of FID signals was performed using a PC operated integration system (BRUKER ChromStar).

Analytical procedures were calibrated with commercial gas standards (LINDE, CH_4; MESSER, Gas Mixture N 19). The detection limit is approx. 40 pmol L^{-1} and the unit operates linear up to 40 nmol L^{-1}. The precision is approx. 5 % of the measured value.

Dissolved oxygen

Concentrations of dissolved oxygen in water samples were determined on board according to the Winkler method.

Measurements were performed automatically with an autotitrator (METROHM Titroprozessor 686), which was provided by the Institut für Organische Chemie, Abteilung für Organo-Meereschemie, Hamburg. The system was calibrated at least once daily with a standard solution of potassium iodide, potassium iodate and sulphuric acid.

4.2.4 First investigations and results

In the following chapter first investigations and results as well as a short discussion of oceanography and waterchemistry at Sula-Ridge in July/August 1999 are given.

4.2.4.1 Physico-chemical results

CTD data were generally recorded for the entire water column and files averaged for 0,25 m depth intervals. Fig. 4.2-1. gives an example of the temperature and salinity profile recorded close to the deep water coral reef complex at Sula Ridge (station 23 MS).

During POS 254 the thermocline was positioned at about 40 to 50 m waterdepth. Water temperatures decreased slightly between 150 m dephts and seafloor. Temperatures of about 7,6 °C were observed in bottom waters.

Salinities increased generally from surface down to about 150 m waterdepth, while relatively constant values were present below 150 m (up to 35,24). The temperature-salinity profiles of the other hydrocasts were similar to that of station 23 MS showing no temperature or salinity anomalies (see Appendix B).

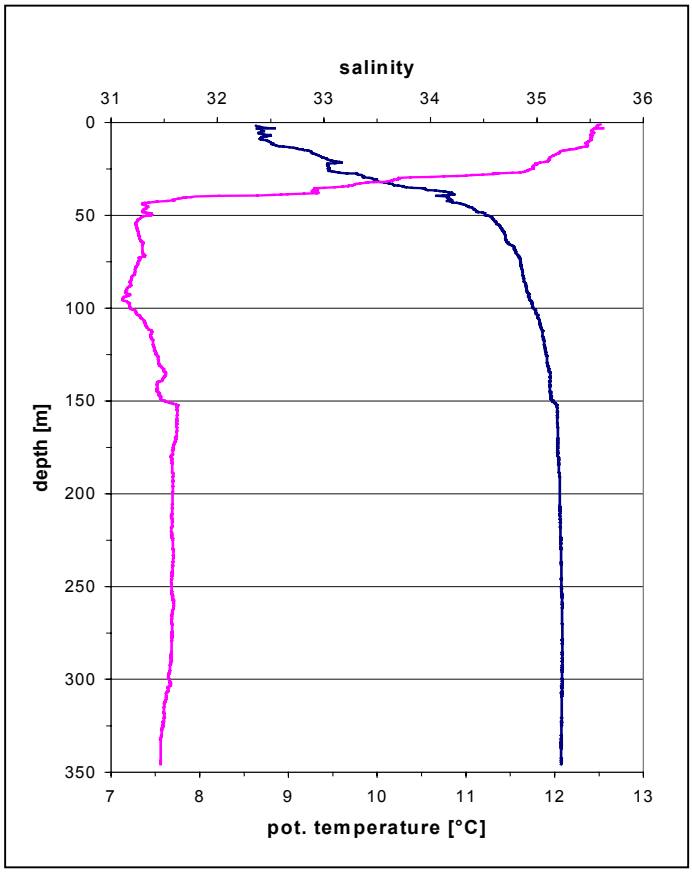

Fig. 4.2-1. Temperature-salinity profile (down-branch) at station 23 MS (64:05:07N, 08:06:50E)

These results are in accordance with findings of former investigations (e.g. R/V Victor Hensen Cruise 24/95) and corroborate that at present there are basically two distinguishable watermasses at the Sula Ridge area (Helland-Hansen and Nansen, 1909; Mork, 1981). As stated earlier (see Chapter 4.1.2) the Norwegian Coastal Current (NCC) supplies surface waters with salinities below 35, while the more dense water masses are formed by the North Atlantic Current (NAC) (Eide, 1979).

However, the targets of this expedition were to characterize ocenographic and chemical settings within the coral-sponge ecosystem and thus our investigations focussed on the lowermost 200 m of the water column.

During POS 254 the thermocline and a salinity mixing zone occured at least 80 m above the reef top. As no small scale deviating values in temperature and salinity were found in deep waters at Sula Ridge we suggest, that they consist of NAC and are relatively homogeneous.

4.2.4.2 Hydrochemical results

Water samples have been taken during 8 hydrocasts at 7 different locations and during 4 out of 8 dives (Fig. 4.2-2.)

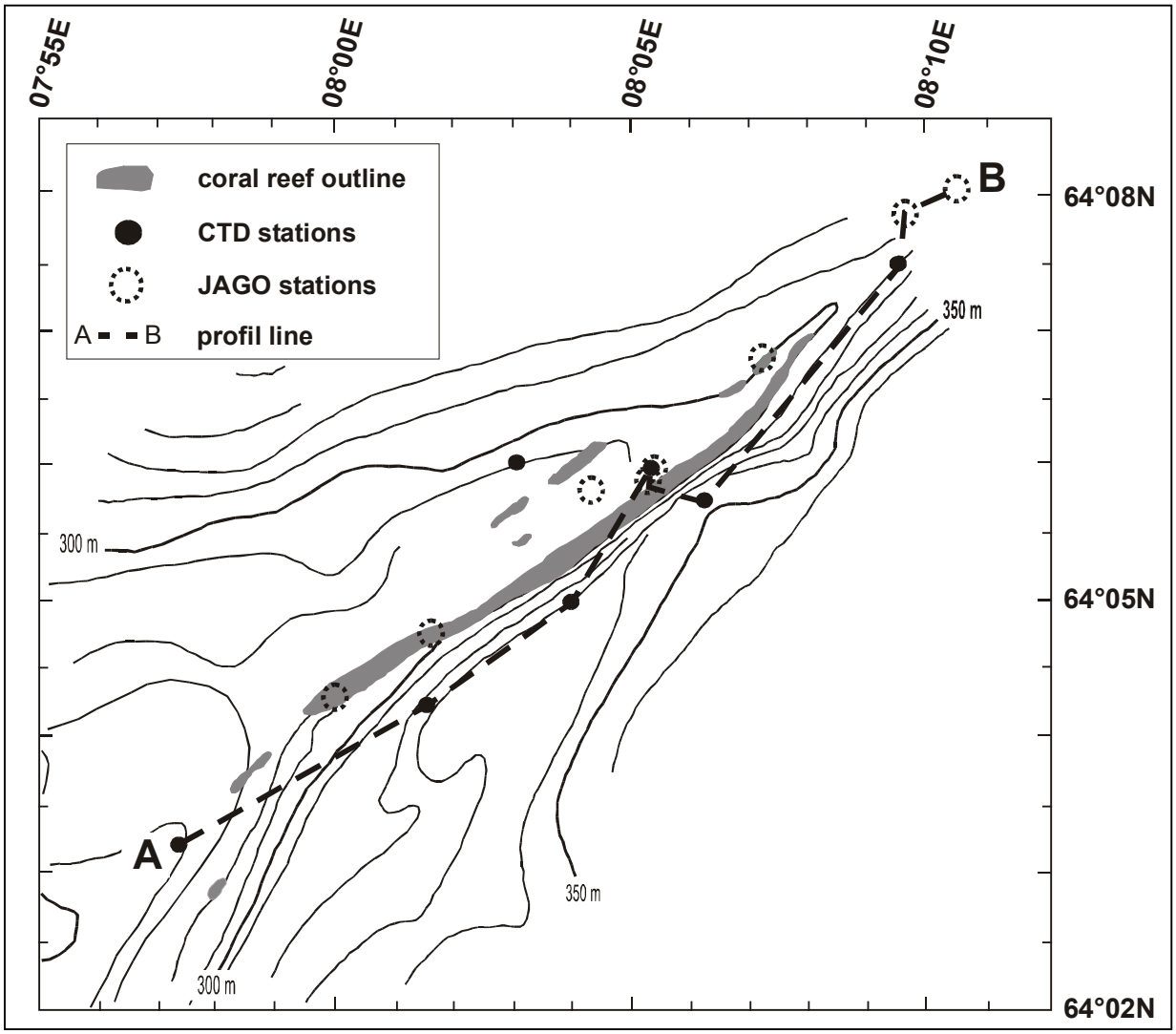

Fig. 4.2-2. Overview of all sampling sites (POS 254).

An overview of all investigated parameters is given in table 4.2-2 (Chapter 4.2.2). All data are listed in the Appendix C.

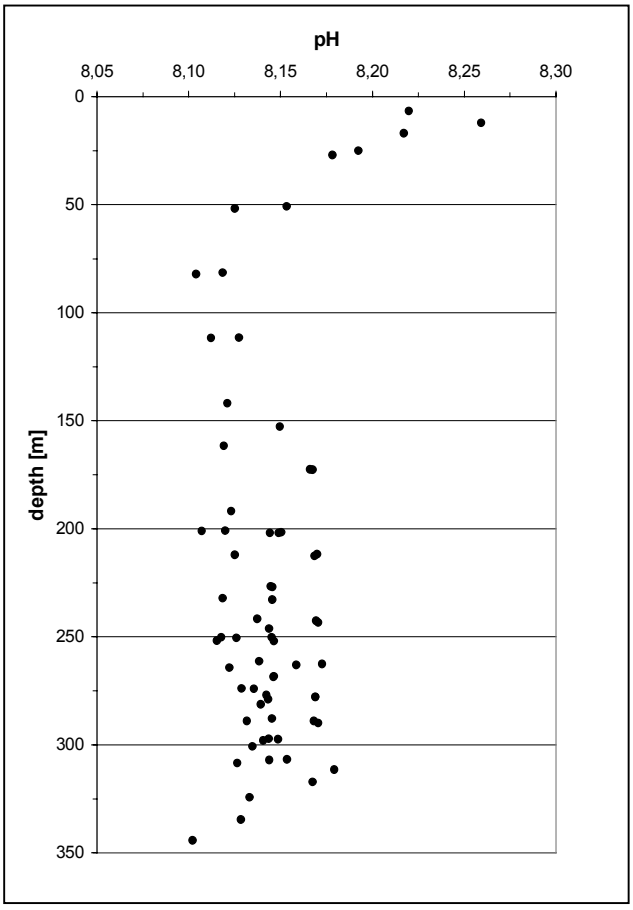

Fig. 4.2-3. *in situ* pH values at Sula Ridge

pH

In total 67 measurements were performed. The distribution pattern of pH values in the water column (Fig. 4.2-3.) matches the CTD temperature profil and indicates, that this parameter is principally influenced by the two main water masses mentioned above.

Highest values (up to pH 8,26) were found in the surface water mass of the NCC. Samples between 50 to 335 m water depth (NAC) exhibit constant pH values (pH 8,11 to 8,18). The lowest pH (8,10) occurred at 344 m close to the seafloor and no significant changes in pH were observed in proximity to the reef complex.

DISSOLVED CARBON SPECIES

Dissolved inorganic carbon (DIC)

Altogether, 72 samples were obtained for measurements of DIC (ΣCO_2) concentrations. The results were normalized to a constant salinity yielding concentrations between approx. 2.120 and 2.160 µmol kg^{-1}.

DIC concentrations decreased in the uppermost 200 m with increasing depth (Fig. 4.2-4.). Below 200 m water depth values vary from 2.121 to 2.135 µmol kg^{-1}

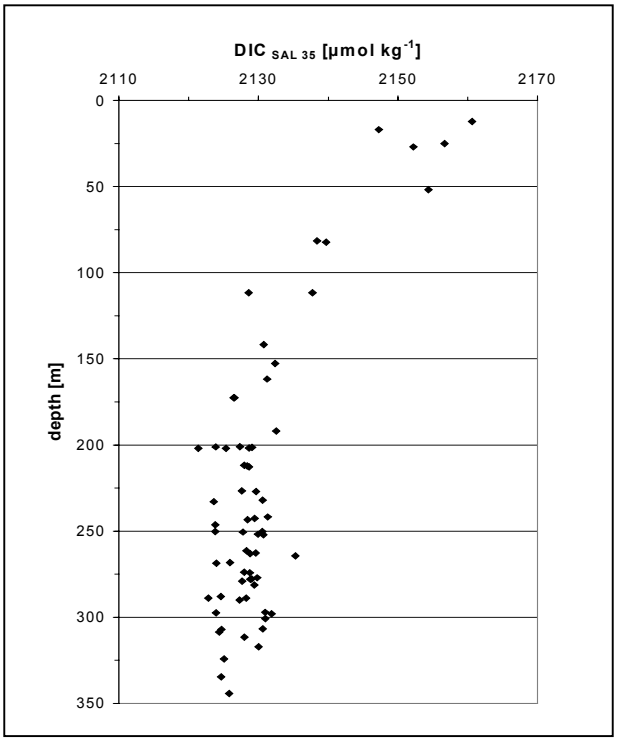

Fig. 4.2-4. DIC concentrations at Sula Ridge

The vertical distribution of DIC exhibits uniform concentrations of about 2.130 µmol kg^{-1} within the reef surrounding water masses (Fig. 4.2-5.).

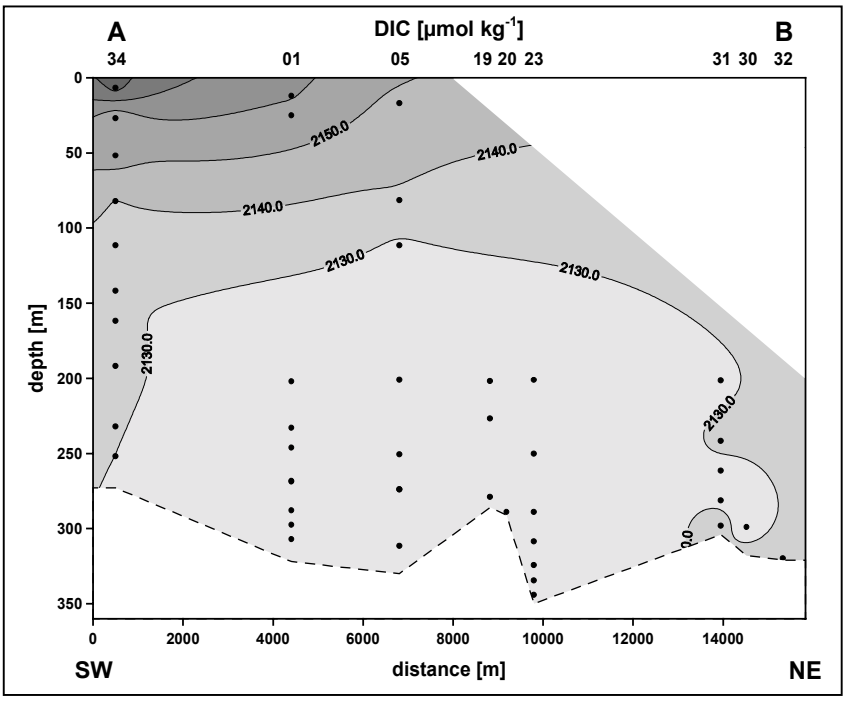

Fig. 4.2-5. Vertical distribution of DIC concentrations (profil line see Fig. 4.2-2.). Numbers above top axis indicate station numbers.

Dissolved organic carbon (DOC)

In total 60 samples were analyzed for DOC yielding concentrations between 0,4 and 1,3 mg L^{-1}. Fig. 4.2-6. illustrates a decrease of DOC with increasing depth. Slightly enhanced concentrations (> 0,75 mg L^{-1}) were only observed in southwesterly and central parts of the profile below 200 m depth.

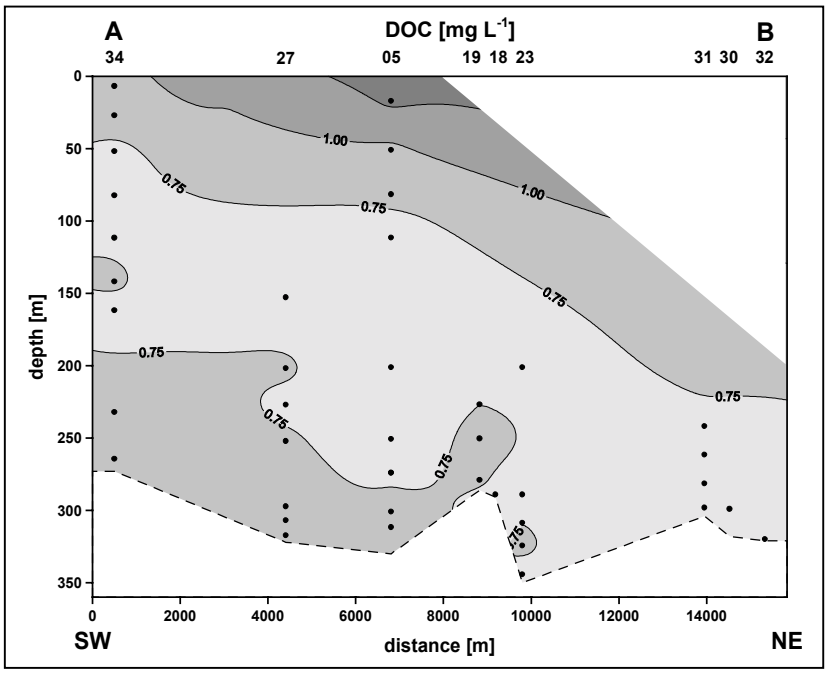

Fig. 4.2-6. Vertical distribution of DOC concentrations (profil line see Fig. 4.2-2.). Numbers above top axis indicate station numbers.

NUTRIENTS

In order to characterize the availability of nutrients in Sula Ridge waters, the following parameters of 63 samples were analyzed: silicate, ammonia, nitrite, nitrate and phosphate. Specific distribution patterns of nutrients within the water column enabled to classify typical concentration areas (Tab. 4.2-3.).

depth [m]	silicate	ammonia	nitrite	nitrate	phosphate
0 - 50	n.d. - 3,3	0,46 - 1,10	0,05 - 0,11	n.d. - 4,8	0,02 - 0,08
50 - 150	3,3 - 7,8	0,51 - 1,03	0,04 - 0,29	n.d. - 10,9	0,04 - 0,97
150 - 350	5,3 - 11,9	0,46 - 1,28	0,04 - 0,36	n.d. - 13,3	0,04 - 1,08

Tab. 4.2-3. Concentration ranges (µmol kg^{-1}) of nutrients at Sula Ridge (n.d. = not determined).

The nutrient concentrations mostly scatter around moderate ranges but tend to increase towards depth. Phosphate and nitrate concentrations were depleted in surface waters, probably due to fixation by primary producers. Except for nitrite (192 m) all maximum values were found at 260 - 280 m. There are a few exceptions of this general trend: ammonia within the whole water column as well as phosphate and nitrate in depths below 50 m show relatively constant concentrations.

Unfortunately we did not obtain sufficient samples for a detailed characterization of nutrient contents in the range between 280 m and seafloor. However, the data of near-bottom samples derived from hydrocasts and JAGO dives showed no distinct concentrations compared to surrounding waters.

DISSOLVED GASES

Light dissolved hydrocarbons

Light hydrocarbons (C_1 - C_4) were determined for 49 samples. Here we present only the results for methane.

Methane concentration increased with increasing depth (Fig. 4.2-7.). The near surface samples contained approx. 14,5 nmol L^{-1} and the maximum value (24,4 nmol L^{-1}) was observed at 227 m depth. Below 230 m depth methane concentrations revealed a slight decrease with increasing depth. Of special interest are near-bottom methane concentrations, as strong positive correlations between coral-bank occurences and enhanced concentrations of light hydrocarbons in near-surface sediments have been observed during former studies. Micro-seepages of hydrocarbons are considered to be one controlling factor for the distribution of *Lophelia pertusa* on the continental shelf off mid-Norway (Hovland et al., 1998). However, our preliminary results do not support this assumption.

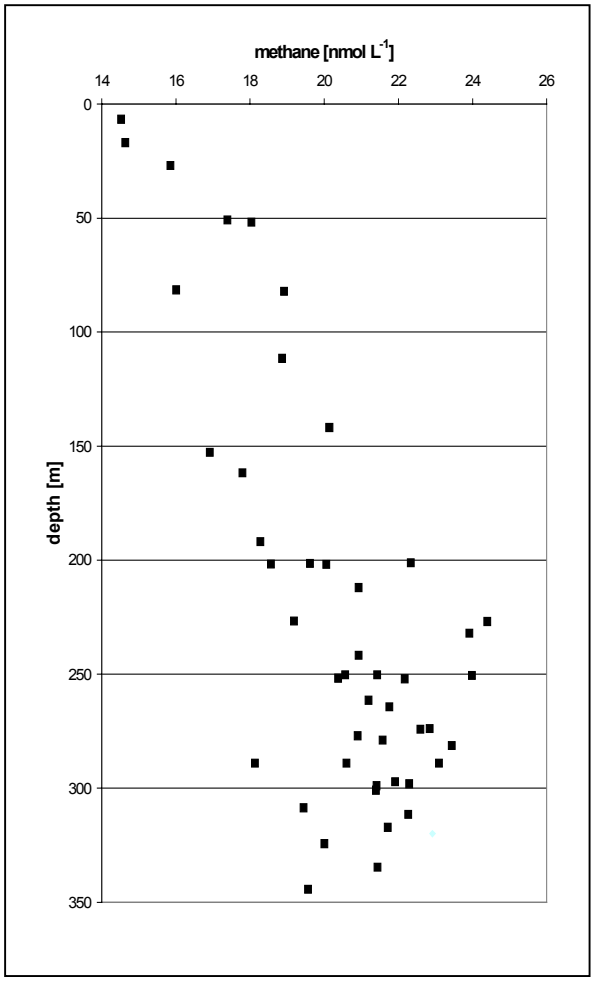

Fig. 4.2-7. Methane concentrations at Sula Ridge

Dissolved oxygen

In total 58 samples were analyzed on board for dissolved oxygen. Due to analytical problems reliable data were only obtained for 41 samples. The oxygen concentrations ranged from 7,6 to 9,0 mg L^{-1} (maximum at station 05 MS, depth 17 m), whereby 60% of the samples showed concentrations 8,5 mg L^{-1}. No depth related gradient was discernible in the water column.

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4.3 Sponges and Sponge distribution of the Deep Water *Lophelia pertusa* reefs of the Sula Ridge area *(J. Reitner)*

4.3.1 Introduction

Main goals of the cruise POS 254 were to collect sponges within their natural habitat and to fixate them for various preparation procedures good for biochemical analyses, histological investigations and molecular phylogenetic analyses. On board the vessel we had to decide which types of sponges are suitable for further investigations. The most important evaluation criterium was simply the biomass and the structure of the sponge mesohyl.

Beside the collection procedure the photographic and video documentation played an important role during the entire cruise. Especially the underwater documentation of sponges within their natural habitat was a great advantage to understand the ecology of different sponge communities observed.

Sponges were collected using a Van Veen grab, a benthic dredge and mainly by the submersible JAGO. As a result of contamination by sediment and damage of tissue during the collection procedure, grab and dregde samples are not suitable for sophisticated biochemical and histological investigations. A lot of important internal bacteria-rich fluids may leak, when the sponge is hurt. Therefore it was absolutely necessary to obtain entirely preserved sponge specimens to protect the internal mesohyl tissue containing the associated bacteria. Most successful collecting of sponges was done by the manned submersible JAGO. The specimens were collected with a robot-arm, so that damage of them was only small. However, it was difficult to collect infaunal sponges like *Oceanapia*, because their root-systems penetrate more then 20 cm into the sediment.

Unfortunately, in the beginning of the cruise the weather conditions were to rough to use the JAGO. From 30.7. - 2.8.99 eight dives with the submersible have been performed during which various facies and collection sites close to the Sula Ridge Lophelia reefs were investigated. These eight dives were sufficient to get an overview on the distribution of sponges in the surroundings of the deep water coral reefs.

Until now, the investigations of the video tapes have not been finished completely.

At the moment we are able to differentiate four main environments:

4.3.1 Rocks

The most prominent environment with sponges are softbottoms in the near surroundings of the *Lophelia*-reefs. Very characteristic lithological elements are rocks of different sizes (cm - m) which are completely overgrown by sessile organisms like soft cnidaria, bryozoans and sponges. These rocks are like islands and a lot of erect sponges settled down on them. Very common are species of *Phakellia* (Axinellida) which look like a large white leaf (20 - 30 cm in diameter) (Fig. 4.3-e). They are characterized by a strong organic skeleton beside simple monaxonic spicules. Aside *Phakellia*, large, very soft white sponges with prominent buds and chimneys are common. These sponges are members of the taxon Mycalidae (Poecilosclerida) (Fig. 4.3-b) and were the only specimen showing fluorescence using underwater UV-light. Large tetractinellid sponges like Pachastrellidae, Stelletidae and Geodiidae are also present on the rock islands. These sponges are of particular interest for the planned investigations. The surfaces of the rocks are nearly completely overgrown by thin sponge crusts of the taxon Hymedesmiidae - an enormous diverse sponge group, but difficult to investigate due to their small biomass.

4.3.2 Softbottoms close to the reefs

The softbottom environments surrounding the rock islands are also important sponge habitats. Sponges adapted to soft bottom environments differ in many aspects from firmground communities. Most soft bottom sponges receive nutrients required from pore - or interstitial water. They probably prefer dissolved organic matter and their ostia are restricted to the sub-sediment part of the sponge body. Oscular pores and larger openings are restricted to the open water column. Common representatives of this sponge type are the Oceanapiidae (Haplosclerida) (Fig. 4.3-c). The main part of the sponge body is located inside the sediment whereas only the oscular-tubes are outside. It seems that this sponge temporarily has an anaerobic metabolism. Further important sponges of this environment are tetractinellid sponges of the taxon *Thenea muricata* (Fig. 4.3-f). All species of the genus *Thenea* are characterized by large tetractinellid spicules protruding outside the sponge and thus forming a hedgehog-like structure.

The sponge thrives on the soft sediment and is budding inside the sediment. Most of the ostia are located inside the sediment. The sponge pumps pore- and interstitidal water. The sponge has a prominent osculum.

As a result of an organic fluff cover on their outside-spicules they are difficult to recognize on the sediment. This fluff is produced by microbial films of still unknown origin. Futhermore it is suggested that these microbial communities are supporting the sponge metabolism. *Thenea* itself has a weak mesohyl with few bacteria only. The choanocyte chambers are very large (100 µm) and differ therefore fundamentally from the Geodiidae. The taxon *Thenea* is adapted to softbottom environments.

4.3.3 Softbottoms far from the reefs

On softbottoms far from the reefs sponges are extremly rare. Thus, only three species of sponges, *Polymastia sol*, small *Thenea* cf. *muricata*, and *Tentorium semisuberites* have been collected during the last JAGO dive (320 m water depth). All these are adapted to live on softbottoms and pump partly porewater out of the sediment. Normally they occur in nutrient poor deep water environments.

4.3.4 *Lophelia*-Reef environment

Within the Lophelia-Reef environment two main facies can be distinguished:

a) the active growing reef environment and
b) a coral rubble zone along the reef front.

Within the active coral growing area (a)) sponges are extremely rare. Small sponges are restricted to dead coral colonies close to the bottom sediment. In between coral structures close to the margin of the reef large tetractinellid sponges like Pachastrellidae and Geodiidae (Fig. 4.3-d) are common.

Sponges are also occuring within the coral rubble zone (b)), where they grow on dead colonies and rubble of corals. The homoscleromorph *Plakortis* sp. (Fig. 4.3-a), a sponge with a dense mesohyl and numerous bacteria, is common. Aside *Plakortis*, up to 30 different species of sponges are present, but determinations are still in progress. Dead coral frameworks are heavily bored by sponges (*Aka* sp.), priapulid worms and further boring worms. The excavated areas are often invaded by highly diverse small sponges, mostly thin poecilosclerids demosponges.

In total a minimum of 50 different sponge taxa (fast determination) has been observed. All collected specimen were photographed using an Olympus Digital Camera. Large biomass rich sponges were divided into several portions for investigations of all incorporated scientific groups. Parts of all collected specimens were fixed for histological and FISH (Fluorescence *In situ* hybridization) investigations.

On board we started decaying experiments with biomass rich sponges to study the importance of anaerobic bacteria (SRB) during this process. One large *Geodia* (Fig. 4.3-d) which showed anaerobic sulfate reducing conditions was collected.

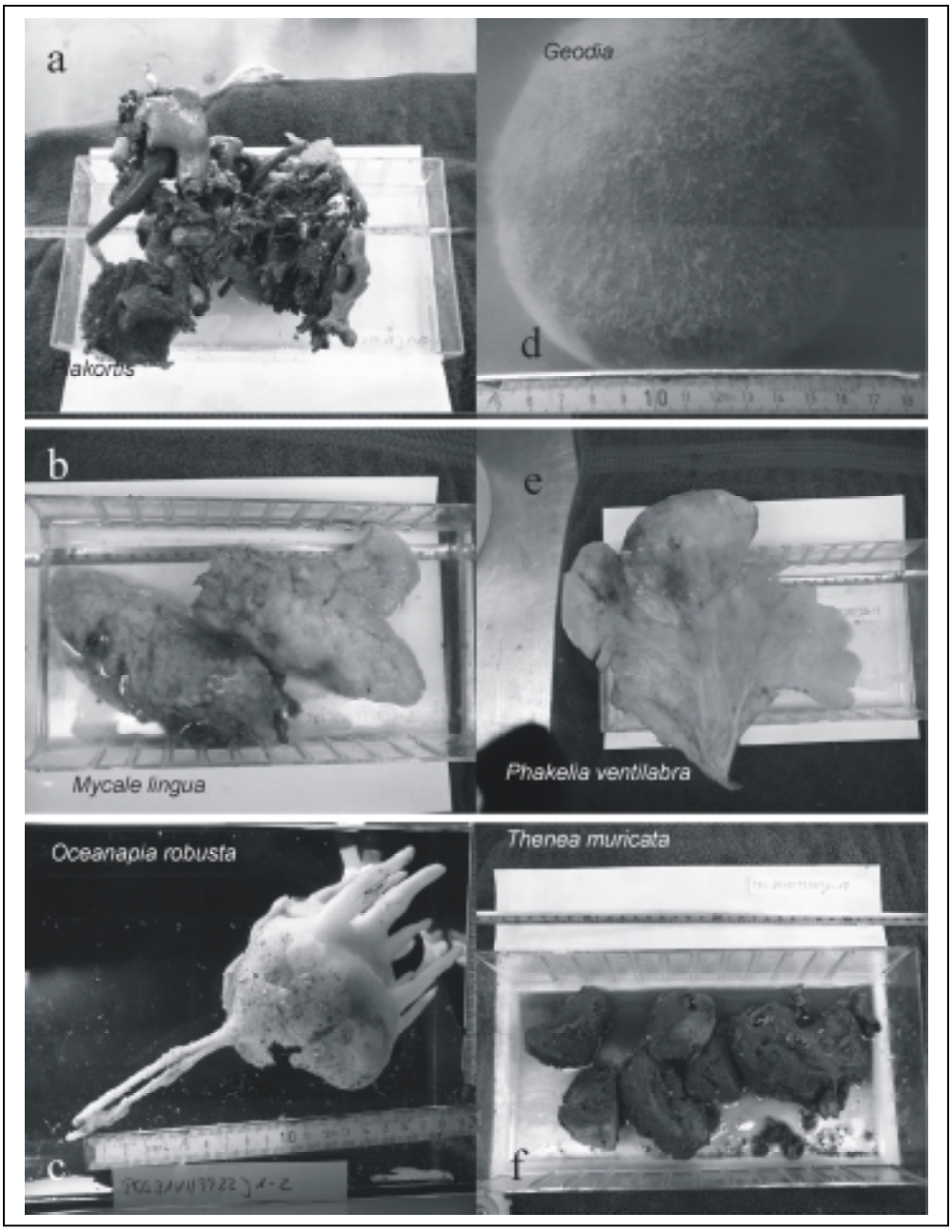


Fig. 4.3- a-d. Selected sponges collected during POS 254

4.4 Sponge-associated bacteria in a boreal deep water reef system

(G. Schumann-Kindel)

4.4.1 Introduction

This report describes the microbial part of the BOSMAN-project (Boreale Schwämme als marine Naturstoffquelle), which started July 1999. Boreal cold water reefs are extended from the north of Norway to the Canaric islands in depths of 100-1000 meters. The interdisciplinary working group investigates the ecology of boreal sponges and is looking for new compounds of general pharmaceutical interest.

One main emphasis of the project are the sponge-associated bacteria (SAB).

The microbiological purpose is to cultivate the SAB and to characterize them in terms of phylogeny and physiology. The experimental combination of different methodological tools is shown in Fig. 4.4-1.

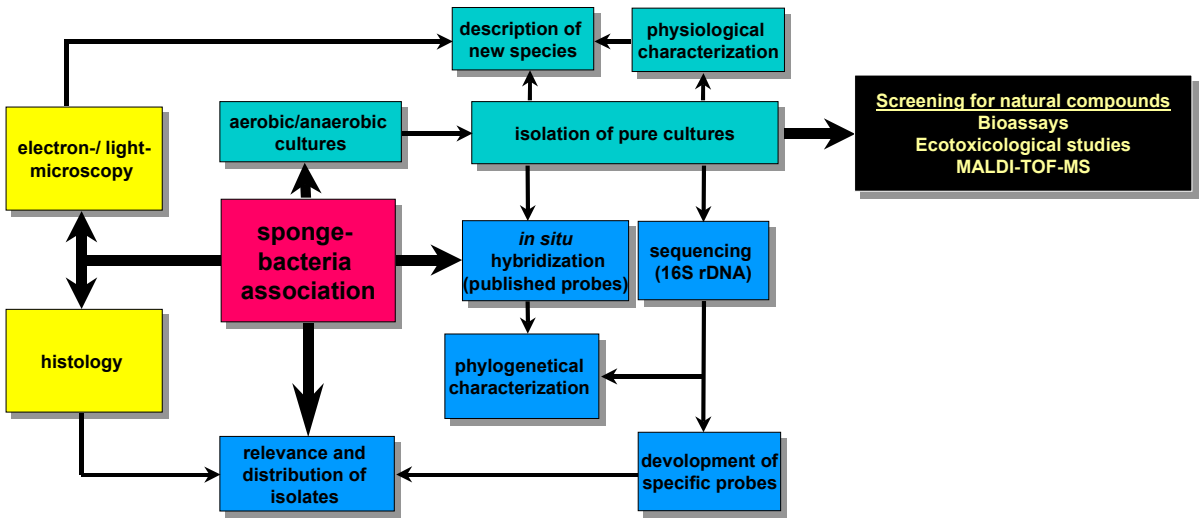
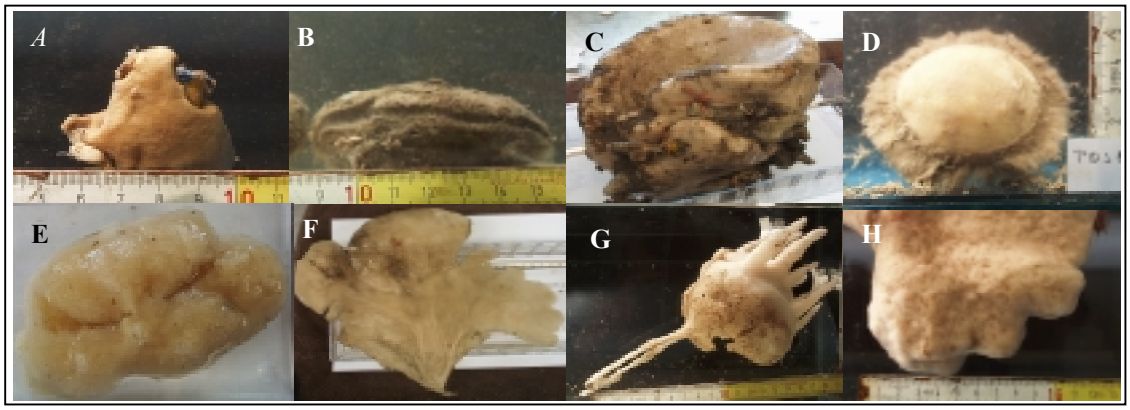


Fig. 4.4-1. Overview of the polyphasic approach for characterization of SAB

Pictures of some sponges, which were chosen for the investigation of their microbial populations, are given in Plate 4.4-1.



Pl. 4.4-1. Sponge-species chosen for cultivation. A: *Plakortis sp.*; B: *Thenea muricata*; C: *Geodia macandrewii*; D: *Polymastia sol*; E: *Mycale lingua*; F: *Phakellia ventilabrum*; G: *Oceanapia robusta*; H: *Petrosia crassa*.

A detailed list of the samples is given in table 4.4-1.

Identifying code	Sample
POS30VII9918J	
1-1	*Hemigellius pumiceus*
1-6	*Haliclona sp.*
1-7	*Geodia macandrewii*
1-7-1	*Geodia macandrewii* - Fluff
1-10	*Placortis sp.*
POS30VII9920J	
2-4	*Phakellia ventilabrum*
POS31VII9922J	
1-14	*Thenea muricata*
1-16	*Geodia macandrewii ("anaerobic")*
POS31VII9924J	
2-7	*div.*
POS01VIII9926J	
1-2a	*Geodia (Ysops) phlegraei*
1-3a	*Mycale lingua*
1-12	*Oceanapia robusta*
POS02VIII9930J	
1-14	*Pachastrella sp.*

Tab. 4.4-1 (continued)

Identifying code	Sample
POS02VIII9932J	
2-1	*Petrosia crassa*
2-5	*Polymastia sol*
POS29VII9907BG	
1-1	Sediment ox.
1-2	*Stycocordyla sp.*
1-3	Sediment anox.
POS30VII9926J	
1-1	Deepwater sample
POS01VIII9928J	
2-1	Sediment
2-4	Mucus of *Lophelia pertusa*

Tab.4.4-1. Overview of the samples with their identifying code

4.4.2 Cultivation strategy

All isolation procedures on board the ship were performed under aseptic conditions. All instruments, glassware, buffers and media were autoclaved or filter sterilized (0.2 µm pore-size) prior to use.

The sponges were cut into blocs (2 x 2 cm) and macerated with an Waring blendor Two speed power with standard size blade. The homogenate was serial diluted both for aerobic and anaerobic cultures. Enrichment and cultivation took place by employing the spread technique for aerobic cultivation and the shake and liquid assay technique for anaerobic organisms. For anaerobic cultivation, the homogenate was immediately suspended in anaerobic medium and O_2 was displaced by a 80:20 (vol/vol) N_2/CO_2 atmosphere.

Dilution series of the homogenated sponge material and other samples

D 10^{-1} : 4.5 ml Seawater (filter sterilized) + 0.5 ml sample

D 10^{-2} : 4.5 ml Seawater (filter sterilized) + 0.5 ml D^{-1}

D 10^{-3} : 4.5 ml Seawater (filter sterilized) + 0.5 ml D^{-2}

D 10^{-4} : 4.5 ml Seawater (filter sterilized) + 0.5 ml D^{-3}

4.4.2.1 Anaerobic cultivation

Anaerobic bacteria were cultivated in an anoxic, bicarbonate-buffered, sulfide- or titanium citrate-reduced mineral salt medium; chemical stock solutions were prepared, as well as agar-shakes, according to Widdel & Pfennig (1981) and aseptically added to the autoclaved medium.

Agar-shakes

For isolation basal media were supplemented with 10 mM lactate, 10 mM formate and a combination of 10 mM ethanol/10 mM propionate/5mM butyrate, respectively. For sulfate reducing bacteria, Na_2SO_4 was supplemented to all enrichments at a final concentration of 10 mM.

Liquid enrichment cultures

Additional cultures supplemented with Na_2SO_4 for further enrichment of SAB were made: 20 mM acetate, 10 mM methanol, 1% cellulose, 1% chitin, 2 mM trimethoxy-benzoate/ 2mM benzoate and without any supplementation. All agar-shakes and liquid cultures were incubated at 8 °C.

4.4.2.2 Aerobic conditions

All agar-plates and liquid cultures were incubated at 8 °C.

Agar plates

For aerobic cultivation Zobell´s medium (commercial: marine agar, Difco) was used as per description and additionally modified concerning the pH (pH=9). Best conditions for seawater vibrios and species of *Alteromonas* (*Pseudoalteromonas*) are found in Baumann´s medium. For the isolation of *Actinoplanetes,* a Casein-starch agar was employed. Agar plates with Zobell´s medium were inoculated with 100 µl of each dilution whereas the pH-changed medium had been inoculated only with the 10^{-1}- dilution. Baumann´s medium was inoculated with 100 µl of the 10^{-1}-10^{-3} dilution and the Casein-starch agar with the 10^{-1}- and 10^{-2}-dilution.

Liquid enrichment cultures

For enrichment of marine V*ibrionaceae,* 9.9 ml CDC medium 1494 was inoculated with 100 µl homogenated sample. Further enrichment was carried out by using Baumann´s medium supplemented with methanol.

4.4.3 First Results

Out of the great number of collected sponges 14 different species were chosen to cultivate the associated bacteria. First results of the occurrence and number of culturable bacteria either under aerobic or anaerobic conditions were achieved from the 8 sponges, shown in Pl. 4.4-1. The colony forming units (CFU) of organisms growing under aerobic conditions were determined on Zobell´s (MA) and Baumann´s (BM) Medium. The CFU for anaerobic bacteria were counted from all agar shakes of the listed sponges.

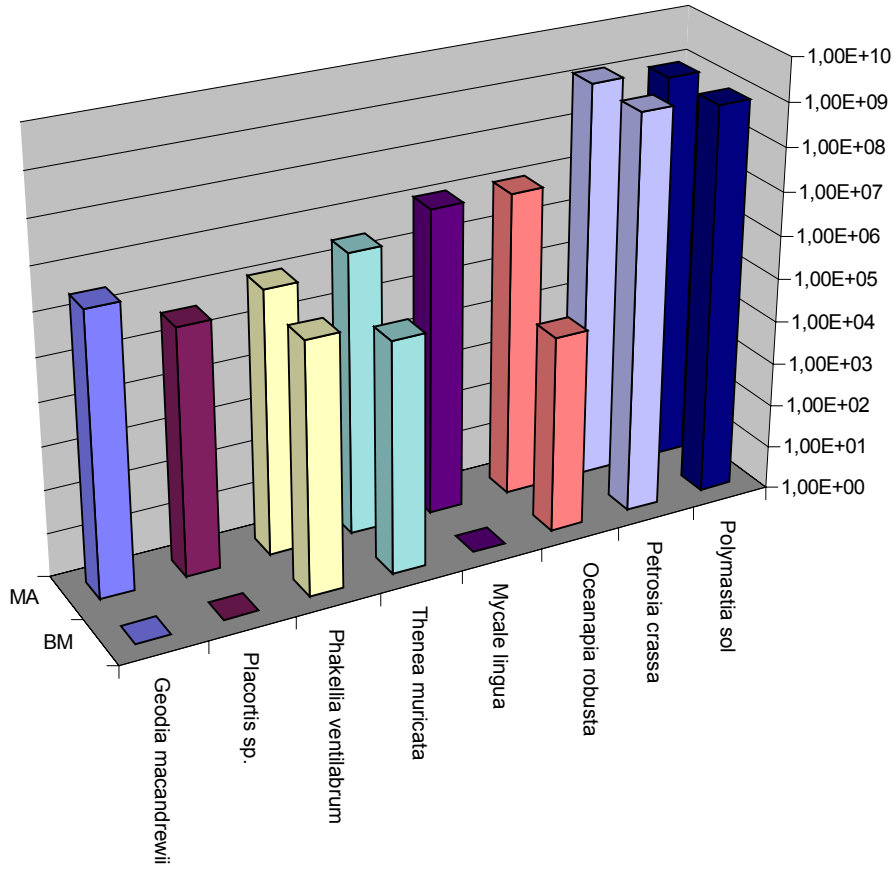


Fig. 4.4-3. Number of sponge-associated bacteria cultured under aerobic conditions as colony forming units (CFU) / g sponge on Zobell´s (MA) and Baumann´s (BM) medium

These first results in colony forming units under aerobic conditions show a significant difference between the two media used and between the different sponge species.

The number of colony forming units ranged from $5x10^5$ to $1.5x10^9$ for Zobell´s and zero to $1.5x10^9$ CFU/g for Baumann´s medium. Nearly the same CFU on both media were found from the homogenate of *Petrosia crassa* and *Polymastia sol,* whereas all other species differed in the number of CFU on the two media. No commonness could be either found within the Tetractinomorpha (*Thenea muricata, Geodia macandrewii, Polymastia sol*) or within the Ceractinomorpha (*Oceanapia robusta, Mycale lingua, Petrosia crassa, Phakellia ventilabrum*).

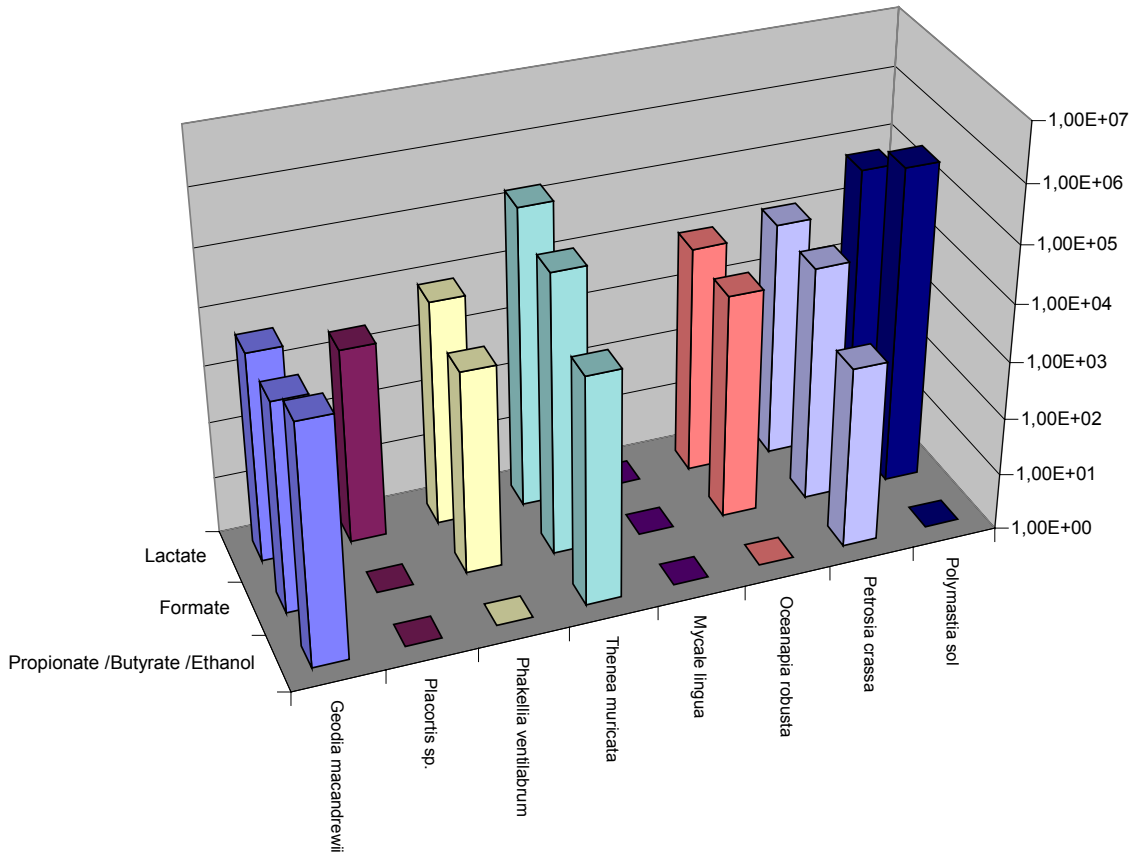


Fig. 4.4-4. Number of sponge-associated bacteria cultured under anaerobic conditions for sulfate reducing bacteria as colony forming units (CFU) / g sponge in agar shakes supplemented with lactate, formate and ethanol/ propionate/butyrate, respectively

The CFU in anaerobic media ranged from zero to $1.8x10^5$ for lactate, zero to $1.3x10^4$ for formate and zero to $1.6x10^4$ for the combination of ethanol/propionate/butyrate. In general, the CFU detected under anaerobic conditions was about 4 magnitudes lower than for aerobic cultures. Also for the anaerobic cultivation, a significant difference between the media and the different sponge species could be seen. Bacteria associated with *Thenea muricata, Geodia macandrewii* and *Petrosia crassa* were able to grow in shakes with all three supplements and these bacteria were the only ones which were capable to utilize the medley or one or two compound of the mixture. Formate was additionally used by SAB of *Polymastia sol, Oceanapia robusta* and *Phakellia ventilabrum.* No CFU could be detected in the shakes inoculated with the homogenate of *Mycale lingua.* This is the only sponge for which no colony was found in the anaerobic cultivation. This result indicates, that the sulfate reducing bacteria detected in the shakes are not from the surrounding seawater, so they are indeed associated with the investigated sponges. This finding serves also as a positive control in that way, that the detected bacteria are only SAB.

Acknowledgements

The logistic help provided by Prof. Dr. Kortum from the Institut für Meereskunde, Kiel as coordinator of R/V POSEIDON and the RF-Shipping Company is greatly acknowledged. The scientific party on board R/V POSEIDON wants to express their sincere thanks to Captain M.Gross, his officers and his crew for cooperation and technical assistance during the submersible operations and associated scientific programme.

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Appendix

A: Operation Statistics

B: MS Profiles

C: Waterchemical Data of the MS Stations

Appendix A: Operation Statistics

CTD = CTD-probe
ES = Echosounder
SSS = Side Scan Sonar
DRD = Bottom Dredge
BG = Van Veen Grab
JAGO = Submersible

Cl = Cable lenght

subm. = submersed; surfd. = surfaced

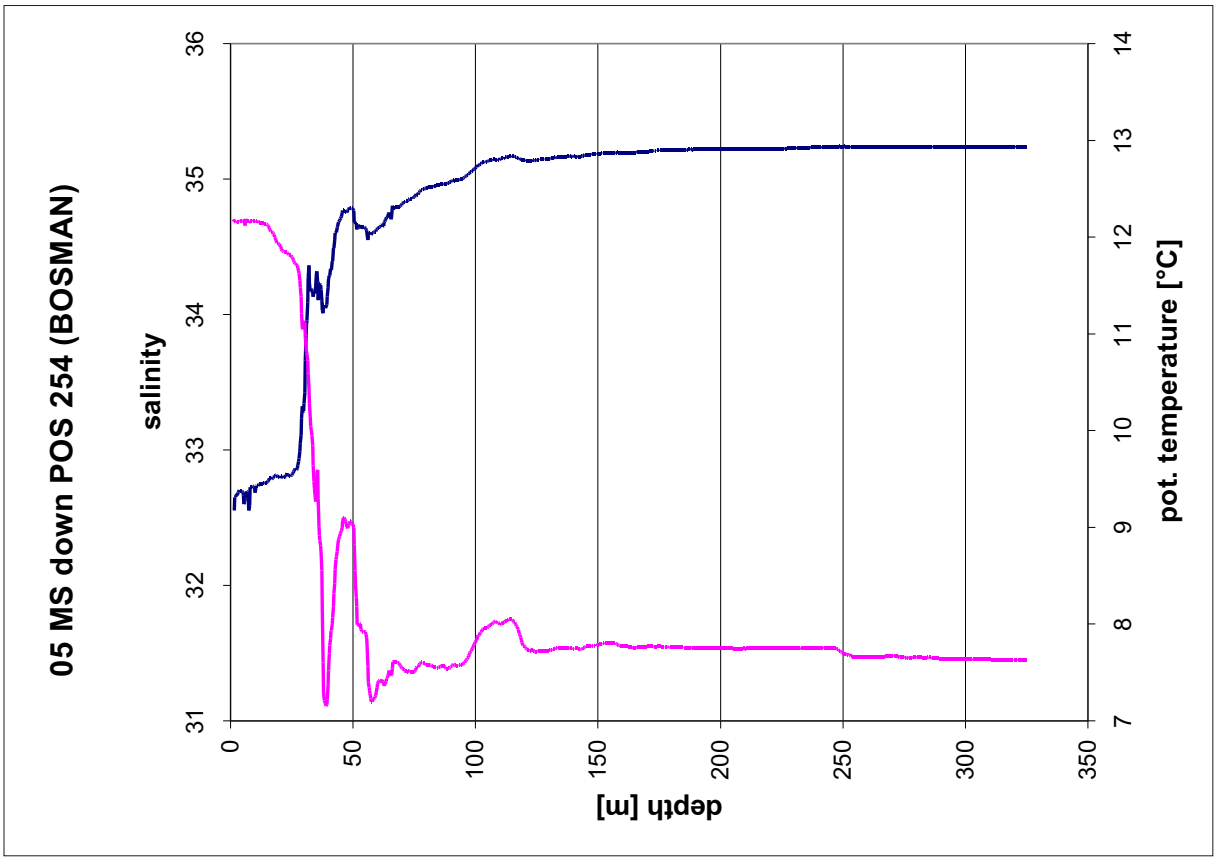
Ship station	Cruise station	Device	Latitude	Longitude	Water Depth	Remarks
Beginning of stations works POS 254						
387	01	CTD	64:04:25N	08:01:50E	325 m	Cl = 313m
388	02-1	ES	64:03:25N	07:55:50E	263 m	Start
			64:07:50N	08:09:00E	307 m	End
389	03-1	SSS	64:08:00N	08:12:00E	324 m	Pre run
			64:07:50N	08:09:00E	306 m	Start
			64:03:20N	07:55:50E	264 m	End
390	02-2	ES	64:03:16N	07:55:66E	256 m	Start
			64:07:41N	08:09:14E		End
391	03-2	SSS	64:07:40N	08:09:10E	310 m	Start
			64:03:16N	07:55:66E	256 m	End
392	02-3	ES	64:03:09N	07:55:82E	254 m	Start
			64:07:32N	08:09:29E	306 m	End
393	03-3	SSS	64:07:32N	08:09:29E	305 m	Start
			64:03:90N	07:55:82E		End
394	04-1	DRD	64:04:60N	07:59:60E	274 m	Start Cl = 600 m
			64:04:50N	07:59:20E	274 m	End
395	04-2	DRD	64:04:00N	08:00:00E	273 m	Start Cl = 600 m
			64:04:00N	08:00:00E	273 m	End
396	05	CTD	64:05:00N	08:04:00E	332 m	Cl = 322 m
397	06-1	ES	64:03:00N	07:56:00E	262 m	Start
			64:07:20N	08:09:50E		End
398	06-2	ES	64:07:15N	08:09:61E	326 m	Start
			64:02:92N	07:56:13E	254 m	End
399	06-3	ES	64:02:83N	07:56:28E	260 m	Start
			64:07:06N	08:09:76E	340 m	End
400	06-4	ES	64:06:97N	08:09:92E	349 m	Start
			64:02:74N	07:56:44E	260 m	End
401	06-5	ES	64:02:65N	07:56:58E	261 m	Start
			64:06:88N	08:10:07E	354 m	End
402	06-6	ES	64:06:79N	08:10:22E	368 m	Start
			64:02:56N	07:56:74E	265 m	End
403	06-7	ES	64:02:47N	07:56:90E	273 m	Start
			64:06:70N	08:10:37E	378 m	End
404	06-8	ES	64:06:61N	08:10:52E	370 m	Start
			64:02:38N	07:57:02E	282 m	End
405	06-9	ES	64:02:30N	07:57:20E	288 m	Start
			64:06:52N	08:10:66E		End
406	07	BG	64:04:30N	08:01:00E	295 m	Cl = 315 m
407	08	BG	64:04:30N	08:00:82E	276 m	Cl = 299 m
408	09	BG	64:04:31N	08:00:60E	244 m	Cl = 264 m
409	10	BG	64:04:50N	08:00:64E	276 m	Cl = 286 m
410	11	BG	64:04:59N	08:00:69E	280 m	Cl = 290 m

Appendix A: Operation Statistics

Ship-Station	Cruise-Station	Device	Latitude	Longitude	Water Depth	Remarks
411	12-1	BG	64:04:80N	08:01:57E	286 m	Cl = 305 m
412	12-2	BG	64:04:84N	08:01:49E	280 m	Cl = 305 m
413	13	BG	64:04:80N	08:01:63E	257 m	Cl = 281 m
414	14	BG	64:04:81N	08:01:69E	250 m	Cl = 275 m
415	15	BG	64:05:00N	08:02:35E	268 m	Cl = 308 m
416	16	CTD	64:06:00N	08:03:00E	294 m	Cl = 286 m
417	17-1	SSS	64:08:40N	08:13:60E	360 m	Pre run
			64:07:20N	08:09:40E	322 m	Start
			64:03:00N	07:56:00E	359 m	End
418	17-2	SSS	64:07:10N	08:09:60E	332 m	Start
			64:02:92N	07:56:13E	260 m	End
419	17-3	SSS	64:07:06N	08:09:76E	338 m	Start
			64:02:80N	07:56:30E	263 m	End
420	18	JAGO	64:05:90N	08:05:60E	263 m	subm.
			64:05:80N	08:05:50E	260 m	surfd.
421	19	CTD	64:05:90N	08:05:40E	286 m	Cl = 277 m
422	20	JAGO	64:05:87N	08:05:43E	285 m	subm.
			64:05:60N	08:04:90E	286 m	surfd.
423	21	SSS	64:08:00N	08:14:00E	366 m	Start
			64:06:97N	08:09:92E		End
	22-1	ES	64:05:75N	08:12:00E	387 m	Start
			63:59:00N	07:52:00E	273 m	End
424	22-2	ES	63:59:25N	07:51:50E	267 m	Start
			64:06:00N	08:11:50E	377 m	End
425	22-3	ES	64:06:25N	08:11:00E	363 m	Start
			63:59:25N	07:51:00E	267 m	End
426	22-4	ES	63:59:50N	07:50:50E	257 m	Start
			64:06:50N	08:11:00E		End
427	22	JAGO	64:04:50N	08:01:40E	285 m	subm.
			64:04:60N	08:01:40E	280 m	surfd.
428	23	CTD	64:05:70N	08:06:50E	357 m	Cl = 340 m
429	24	JAGO	64:04:67N	08:01:42E	269 m	subm.
			64:04:80N	08:01:30E	277 m	surfd.
430	25-1	SSS	64:08:20N	08:14:10E	367 m	Pre run
			64:06:97N	08:09:92E	351 m	Start
			64:02:74N	07:56:44E	252 m	End
431	25-2	SSS	64:07:24N	08:09:45E	319 m	Start
			64:03:00N	07:55:97E		End
432	26	JAGO	64:05:80N	08:04:40E	293 m	subm.
			64:05:70N	08:04:60E	269 m	surfd.
433	27	CTD	64:04:25N	08:01:60E	322 m	Cl = 315 m
434	28	JAGO	64:06:80N	08:07:26E	303 m	subm.
			64:06:60N	08:07:50E	276 m	surfd.
435	29-1	SSS	64:08:50N	08:12:90E	346 m	Pre run
			64:04:32N	08:09:29E	309 m	Start
			64:03:40N	07:56:80E	273 m	End
436	29-2	SSS	64:07:41N	08:09:14E	304 m	Start
			64:03:16N	07:55:66E	256 m	End
437	30	JAGO	64:07:80N	08:09:80E	318 m	subm.
			64:07:80N	08:10:00E	299 m	surfd.
438	31	CTD	64:07:50N	08:09:50E	304 m	Cl = 296 m

Appendix A: Operation Statistics

Ship-Station	Cruise-Station	Device	Latitude	Longitude	Water Depth	Remarks
439	32	JAGO	64:08:10N 64:07:80N	08:10:52E 08:10:80E	320 m 325 m	subm. surfd.
440	33-1	SSS	64:0910N 64:07:50N 64:05:60N	08:11:50E 08:09:00E 08:06:20E	334 m 310 m 344 m	Pre run Start End
441	33-2	SSS	64:05:60N 64:07:50N	08:06:20E 08:09:00E	344 m 310 m	Start End
442	33-3	SSS	64:07:50N 64:05:60N	08:09:30E 08:06:50E	 350 m	Start End
443	34	CTD	64:03:20N	07:57:40E	273 m	CI = 261 m
End of station works POS 254						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salinity
pot. temperature [°C]
depth [m]
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32
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10
11
12
13
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0
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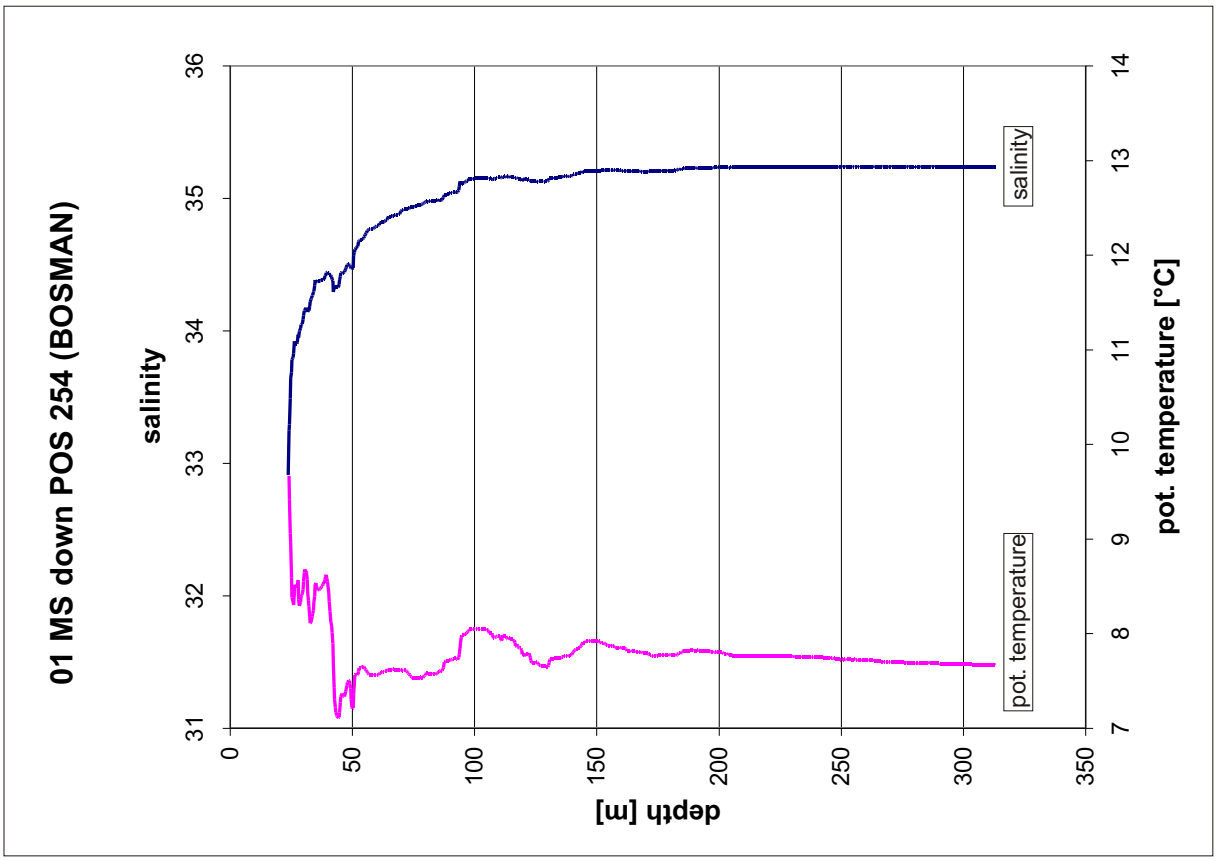
100
150
200
250
300
350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salinity
pot. temperature [°C]
depth [m]
salinity
pot. temperature
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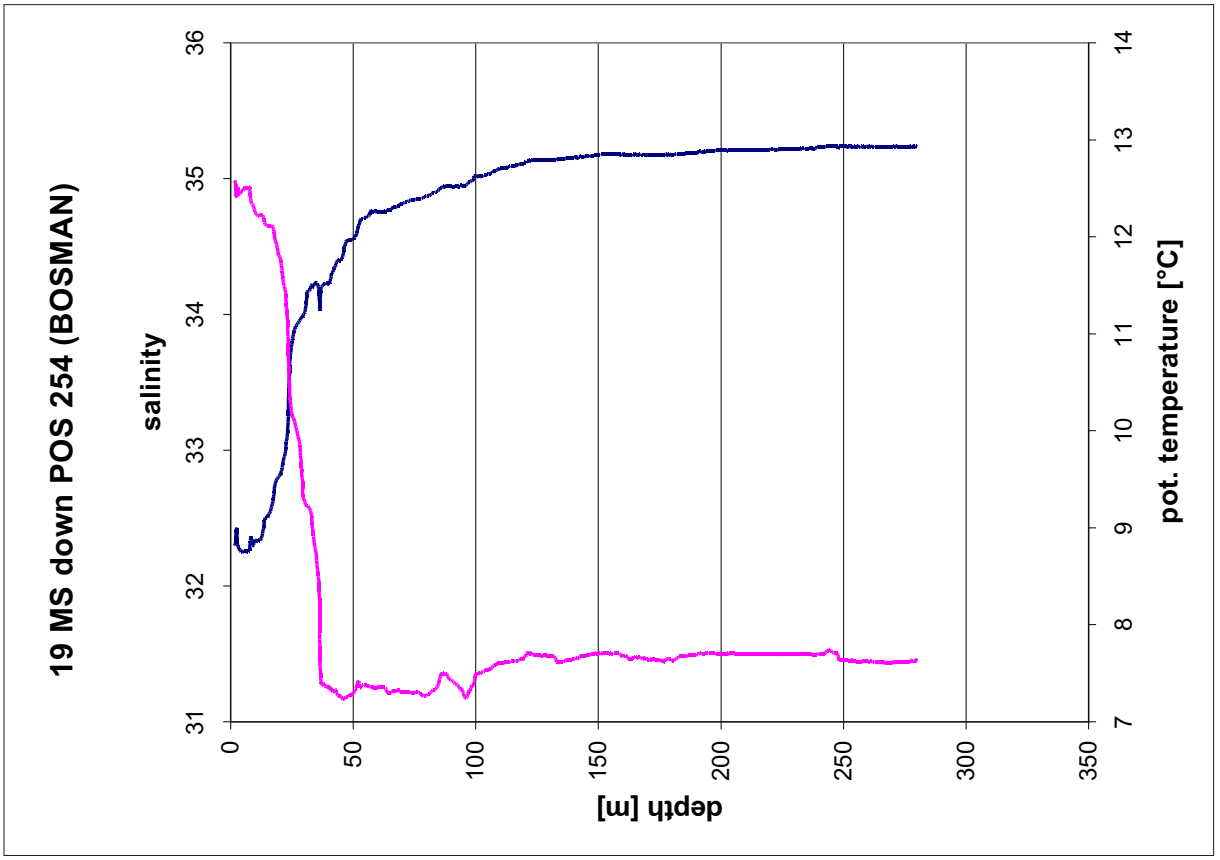
50
100
150
200
250
300
350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salinity
pot. temperature [°C]
depth [m]
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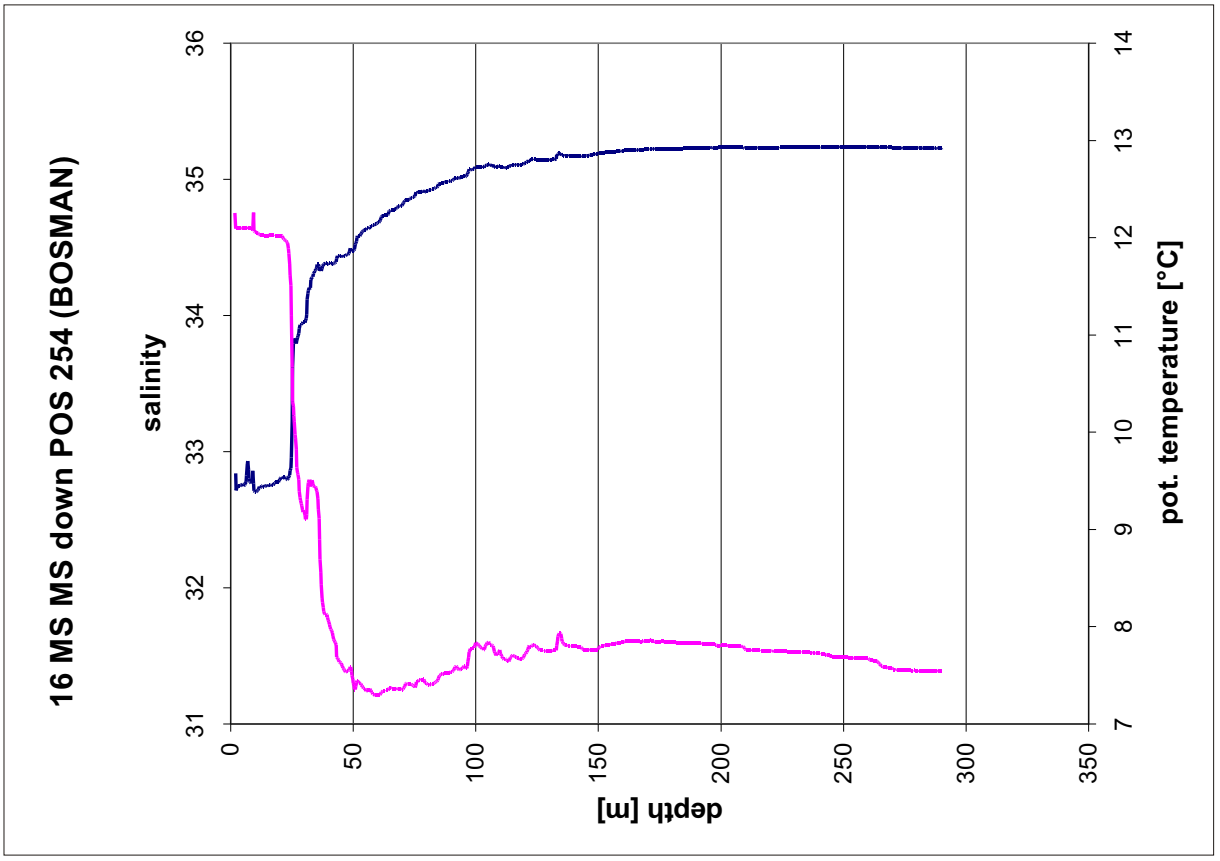
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salinity
pot. temperature [°C]
depth [m]
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32
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9
10
11
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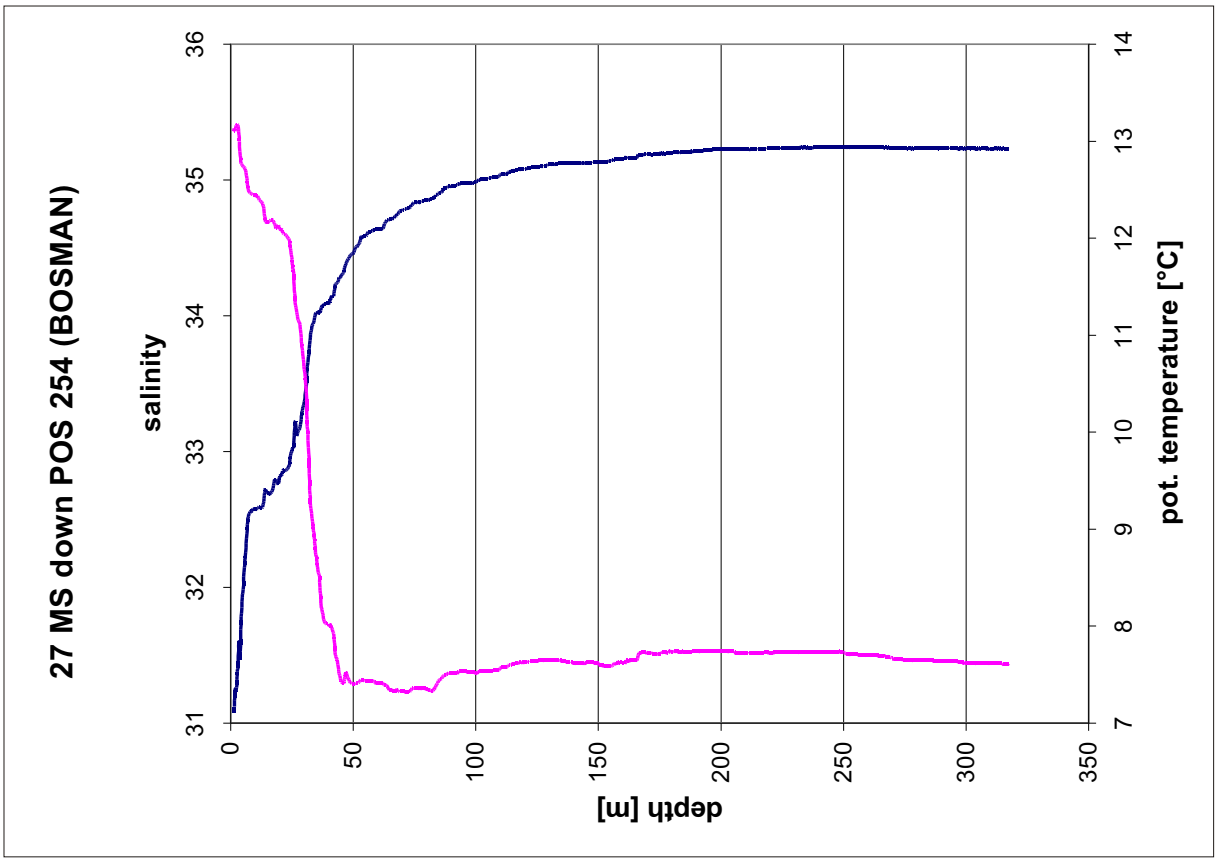
13
14
0
50
100
150
200
250
300
350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salinity
pot. temperature [°C]
depth [m]
31
32
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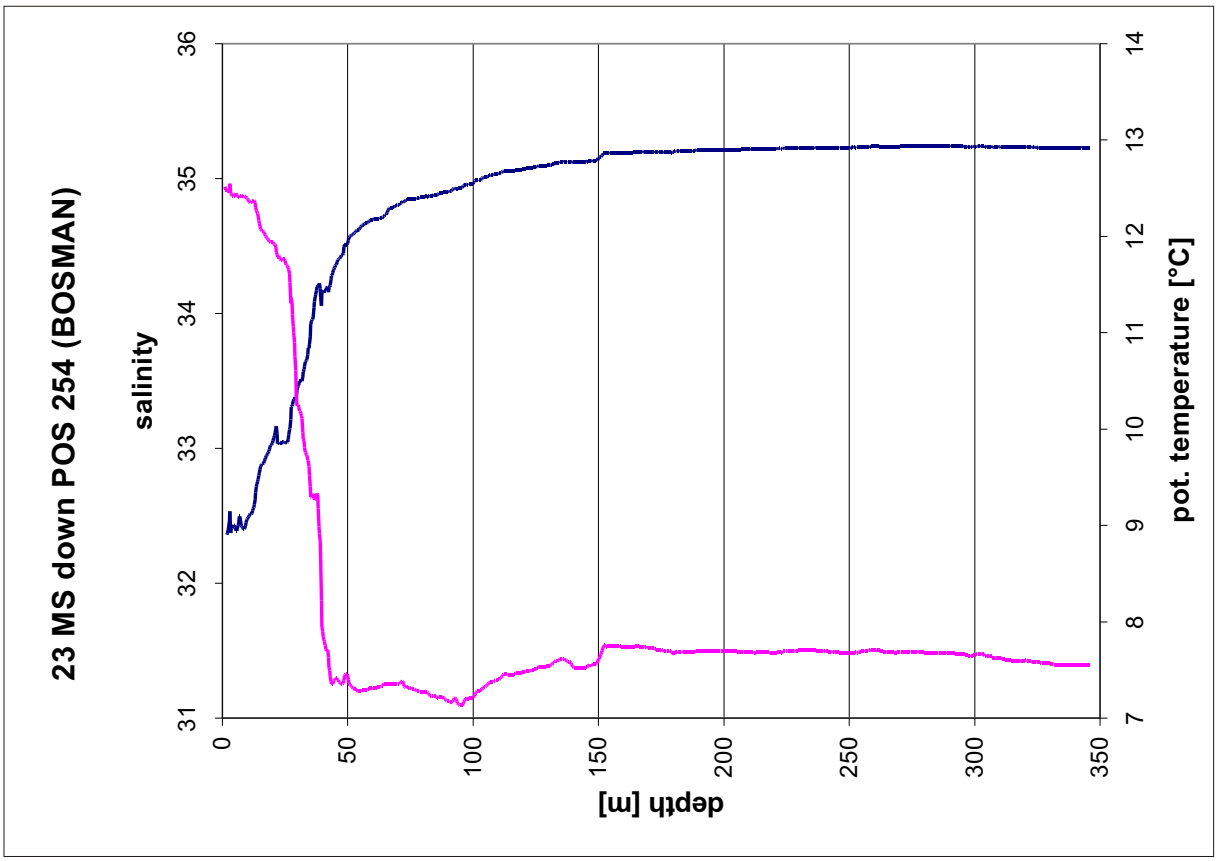
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pot. temperature [°C]
depth [m]
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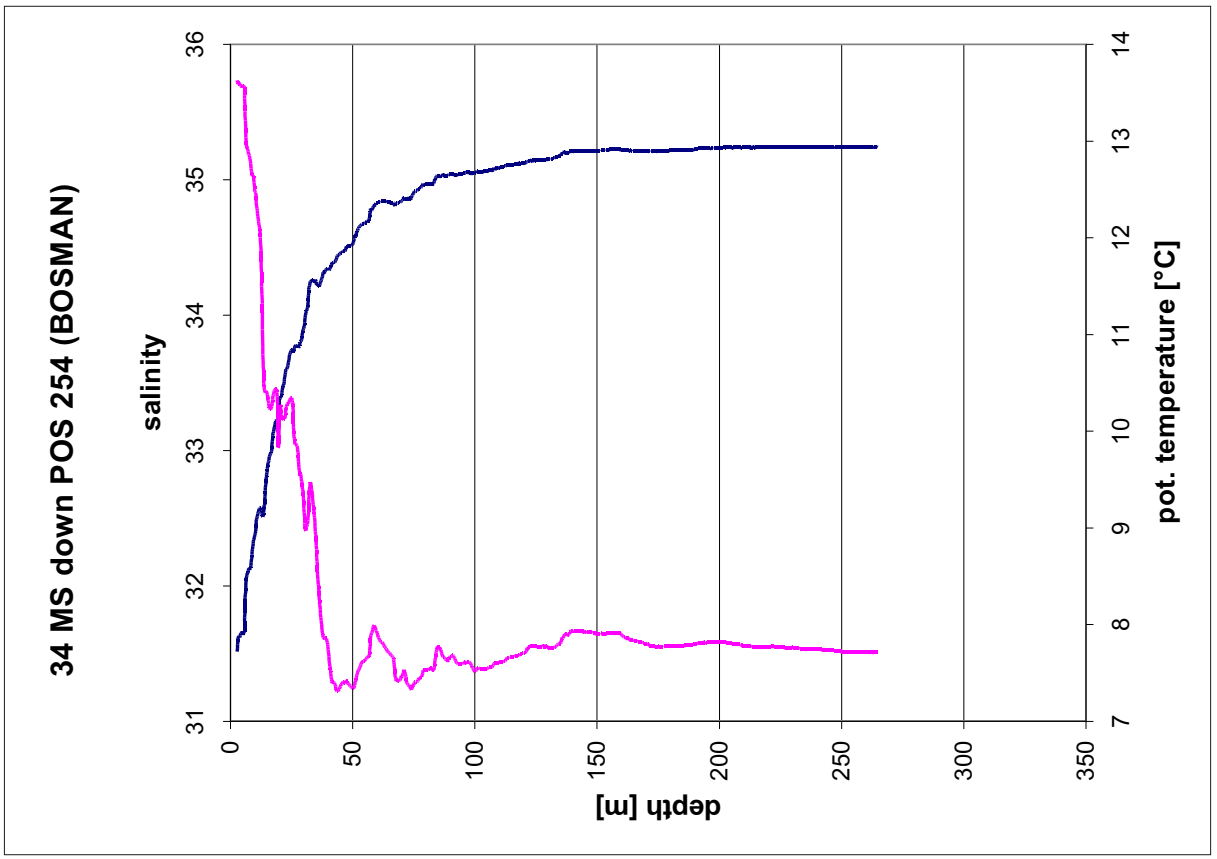
250
300
350


34 MS down POS 254 (BOSMAN)
salinity
pot. temperature [°C]
depth [m]
31
32
33
34
35
36
7
8
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10
11
12
13
14
0
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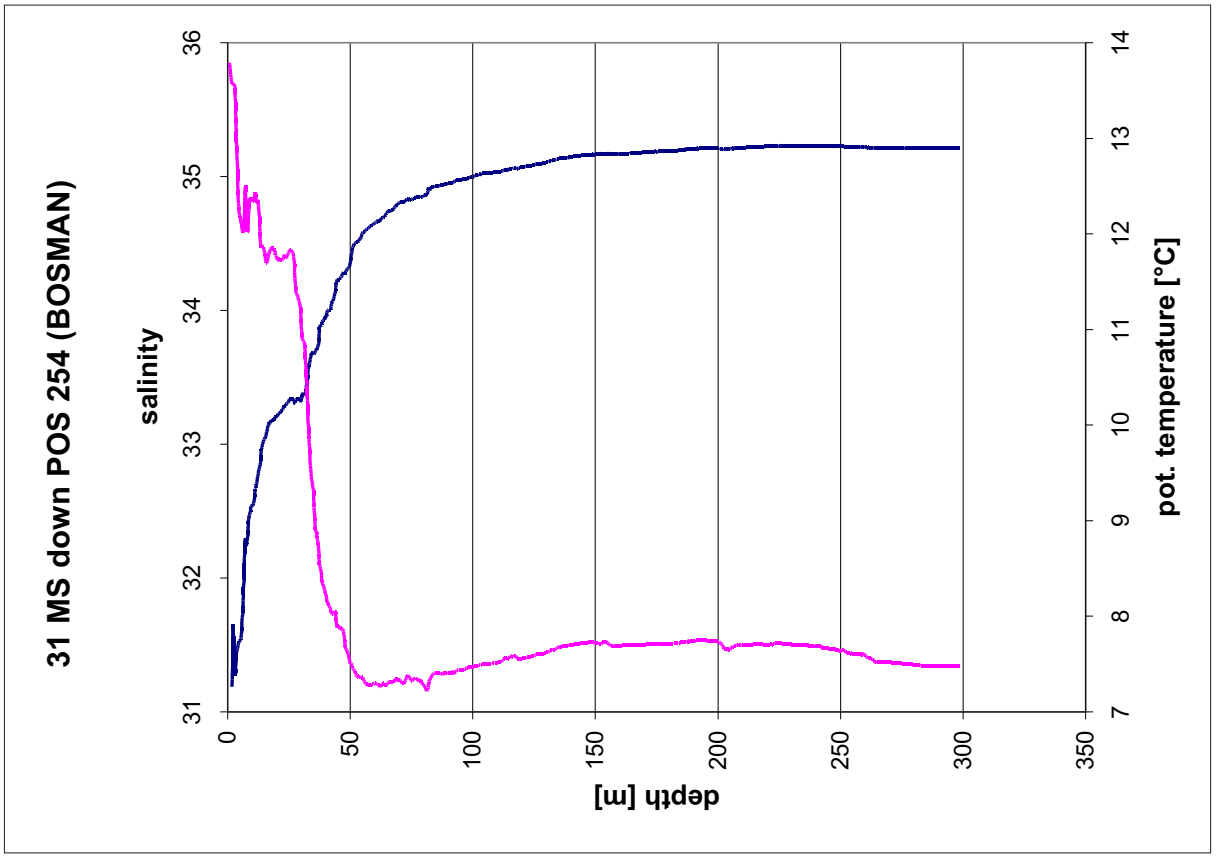
100
150
200
250
300
350


31 MS down POS 254 (BOSMAN)
salinity
pot. temperature [°C]
depth [m]
31
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10
11
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13
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0
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100
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200
250
300
350

Appendix C: Waterchemical Data of the MS stations

Cruise station	water depth [m]	salinity [psu]	pH *in situ*	DIC $_{SAL35}$ [µmol kg^{-1}]	DOC [mg L^{-1}]	dissolved oxygen [mg L^{-1}]	dissolved methane [nM]
01 MS	**12,1**		8,259	2160,62			
	25,0		8,192	2156,68			
	202,0		8,149	2121,38			
	232,9		8,145	2123,59			
	246,3		8,144	2123,80			
	268,4		8,147	2125,91			
	268,7		8,146	2123,99			
	287,9		8,145	2124,61			
	297,5		8,149	2123,95			
	307,1		8,144	2124,69			
05 MS	**17,0**		8,217	2147,27	1,29	9,03	14,64
	50,8		8,153	2130,60	0,95	8,35	17,39
	81,5		8,119	2138,39	0,82	7,74	16,01
	111,5		8,127	2128,60	0,62	8,24	18,87
	201,0		8,120	2127,35	0,55	8,73	27,87
	250,6		8,126	2127,81	0,53		23,99
	273,9		8,129	2127,97	0,57		22,85
	274,1		8,136	2128,76	0,70		22,60
	300,9		8,135	2130,98	1,21	3,70	21,40
	311,6		8,179	2127,98	0,85		22,27
	327,0						
16 MS	**172,6**		8,166	2126,58	0,73	8,36	
	172,6		8,168	2126,45	0,75	8,87	
	211,9		8,170	2127,95		8,70	
	212,7		8,169	2128,65	0,89	8,52	
	242,6		8,170	2129,45	0,68	8,63	
	243,4		8,171	2128,46	0,85	8,81	
	262,7		8,173	2129,61	0,89	8,88	
	263,1		8,159	2128,80	0,65	8,61	
	277,8		8,169	2128,99	0,65	8,88	
	277,9		8,169	2128,87	1,54	8,81	
	289,0		8,168	2128,24	0,70	8,82	
	289,9		8,171	2127,32	0,77	8,86	
18 JA	**289,0**			2130,19	0,54		18,14
19 MS	**202,0**	35,214	8,144	2125,37	0,94	7,86	20,06
	226,7	35,220	8,145	2127,62	0,75	6,57	19,20
	250,3	35,244	8,145	2130,57	0,82	7,92	21,43
	279,0	35,242	8,143	2127,69	0,83	8,71	21,57
20 JA	**289,0**	35,241		2129,79	0,53		20,60

Appendix C:
Physico-chemical and hydrochemical data of the MS stations

Cruise station	water depth [m]	salinity [psu]	pH *in situ*	DIC $_{SAL35}$ [µmol kg^{-1}]	DOC [mg L^{-1}]	dissolved oxygen [mg L^{-1}]	dissolved methane [nM]
23 MS	**201,1**		8,107	2123,88	0,62	8,77	22,35
	250,3		8,118	2123,79		6,94	20,58
	289,0		8,132	2122,84	0,62	8,77	23,10
	308,6		8,127	2124,40	0,75	8,75	19,45
	324,4		8,133	2125,08	0,76	7,91	20,01
	334,7		8,128	2124,66	0,51	8,78	21,44
	344,3		8,102	2125,82	0,73	8,88	19,57
27 MS	**152,7**	35,156	8,150	2132,39	0,63	8,14	16,92
	201,7		8,150	2128,66	0,79	8,46	18,57
	227,0	35,244	8,146	2129,68	0,69	7,65	24,41
	252,1	35,246	8,147	2130,72	0,80	7,59	22,18
	277,1	35,237	8,142	2129,81	0,49	8,81	20,91
	297,2	35,239	8,144	2130,96	0,94	8,18	21,92
	306,8	35,236	8,154	2130,64	0,82	8,16	
	317,2	35,237	8,168	2130,01	0,75	8,83	21,71
30 JA	**299,0**			2127,04	0,50		21,41
31 MS	**201,5**	35,213		2129,11	0,53	6,19	19,62
	241,8	35,298	8,137	2131,34	0,72	6,53	20,93
	261,5	35,219	8,138	2128,27	0,60	8,65	21,20
	281,4	35,221	8,139	2129,41	0,63	8,45	23,44
	298,1	35,221	8,141	2131,91	0,69	7,82	22,30
32 JA	**320,0**			2134,86	0,62		22,92
34 MS	**6,7**		8,220	2182,81	0,89	8,55	14,52
	27,0		8,178	2152,22	0,88	8,21	15,86
	51,8		8,125	2154,37	0,69	6,36	18,03
	82,2		8,104	2139,71	0,74	3,60	18,92
	111,6		8,112	2137,75	0,99	3,91	14,14
	141,9		8,121	2130,77	0,76	6,74	20,15
	161,7		8,119	2131,25	0,73	6,38	17,80
	192,0		8,123	2132,55	1,01	4,93	18,29
	212,2		8,125	2128,41	0,43	6,26	20,93
	232,1		8,118	2130,58	0,78	7,58	23,91
	251,9		8,115	2129,96	0,56	4,95	20,38
	264,4		8,122	2135,32	0,79	8,56	21,76

Appendix C: Waterchemical Data of the MS stations

Cruise station	water depth [m]	phosphate [µmol L^{-1}]	silicate [µmol L^{-1}]	ammonia [µmol L^{-1}]	nitrite [µmol L^{-1}]	nitrate [µmol L^{-1}]
05 MS	**17,0**	0,08	1,78	0,46	0,030	0,28
	50,8	0,73	3,32	1,03	0,206	8,12
	81,5	0,97	8,04	0,82	0,046	10,50
	111,5	0,93	5,76	0,51	0,019	10,94
	201,0	1,00	8,56	0,52	0,032	11,95
	250,6	0,93	7,56	0,52	0,106	12,19
	273,9	0,81	7,35	0,58	0,056	11,82
	274,1	0,70	7,49	0,66	0,053	11,35
	300,9	0,64	5,30	0,34	0,049	11,10
	311,6	0,66	7,22	0,25	0,043	10,93
	327,0	0,19	1,72	1,04	0,086	1,27
16 MS	**172,6**	0,91	7,94	0,74	0,048	11,80
	172,6	0,58	6,38	1,18	0,068	10,65
	211,9	0,94	6,37	1,14	0,097	12,19
	212,7	0,59	6,13	0,65	0,044	10,52
	242,6	0,96	9,83	0,92	0,056	12,27
	243,4	0,93	8,79	1,10	0,072	12,10
	262,7	1,01	8,94	0,64	0,057	12,43
	263,1	0,87	8,88	0,90	0,064	12,21
	277,8	1,08	6,61	2,11	0,061	12,43
	277,9	1,07	9,66	1,04	0,090	13,29
	289,9	0,94	8,86	0,86	0,097	12,41
	289,0	0,76	7,41	0,70	0,067	11,64
18 JA	**289,0**	0,73	5,96	0,85	0,076	11,71
19 MS	**202,0**	1,31	7,55	1,81	0,060	11,92
	226,7	0,94	14,14	0,87	0,071	11,69
	250,3	1,03	10,39	0,70	0,043	12,22
	279,0	0,98	6,11	0,64	0,038	12,22
20 JA	**289,0**	0,73	9,69	10,10	0,048	12,48
23 MS	**201,1**	0,07	9,15	0,53	0,259	5,50
	250,3	0,41	9,61	0,61	0,056	10,52
	289,0	0,58	7,84	0,50	0,127	9,17
	308,6	0,08	21,85	0,53	0,095	4,92
	324,4	0,47	6,99	0,46	0,036	9,00
	334,7	0,07	9,06	0,52	0,424	6,19
	344,3	0,07	10,04	0,54	0,347	1,96

Appendix C: Waterchemical Data of the MS stations

Cruise station	water depth [m]	phosphate [µmol L^{-1}]	silicate [µmol L^{-1}]	ammonia [µmol L^{-1}]	nitrite [µmol L^{-1}]	nitrate [µmol L^{-1}]
27 MS	**152,7**	0,10	6,30	0,71	0,120	11,28
	201,7	0,09	9,50	0,60	0,142	1,81
	227,0	0,34	9,47	0,75	0,314	7,56
	252,1	0,12	10,94	0,58	0,057	1,43
	277,1	0,46	9,09	0,58	0,150	8,55
	297,2	0,47	7,78	0,57	0,236	9,38
	306,8	0,65	10,28	0,65	0,063	10,91
	317,2	0,29	7,72	0,57	0,120	7,48
30 JA	**299,0**	0,34	8,88	0,69	0,190	7,75
31 MS	**201,5**	0,31	7,08	0,67	0,506	6,60
	241,8	0,08	9,02	0,65	0,204	6,50
	261,5	0,06	10,02	0,82	0,343	8,13
	281,4	0,11	10,83	0,65	0,182	8,69
	298,1	0,17	7,80	0,65	0,287	5,94
32 JA	**320,0**	0,07	10,87	0,94	0,182	0,08
34 MS	(double measurements)					
	6,7	0,03	3,31	1,10	0,100	0,16
	27,0	0,04	3,28	0,91	0,114	4,84
	51,8	0,04	5,56	0,63	0,223	2,86
	82,2	0,04	8,39	0,67	0,245	2,41
	111,6	0,16	7,79	0,58	0,292	7,13
	141,9	0,10	7,48	0,62	0,237	0,19
	161,7	0,05	7,20	0,96	0,617	0,53
	192,0	0,32	8,99	0,93	0,358	6,74
	212,2	0,32	6,86	1,03	0,300	6,17
	232,1	0,24	10,14	0,96	0,290	6,48
	251,9	0,38	8,53	0,94	0,252	8,72
	264,4	0,40	11,93	1,28	0,238	8,97